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Development of Animal Waste Facilities for Minimizing Water Pollution

South Dakota State University
Brookings

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COMPLETION REPORT

DEVELOPMENT OF ANIMAL WASTE FACILITIES FOR MINIMIZING WATER POLLUTION

Principal Investigator:

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Project A-036-SDAK
Agreement No. 14-31-0001-3542

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Three methods for controlling water pollution from animal wastes in feedlots are presented. The first method involves confining all wastes and water to the feedlot area until maximum decomposition occurs. The second method involved the use of a minimum area for the feedlot to favor decomposition and treatment of wastes. A system of diversion ditches and drying terraces was used to handle runoff and wastes from a sloped lot. Sample wells were used to study groundwater flow and quality near the terraces. The third method involves the return of feedlot wastes to the land at a rate that does not inhibit full crop production.

KEYWORDS: *Agricultural wastes, *Cattle, *Water pollution control.

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16. Abstract
Three methods for controlling water pollution from animal wastes in feedlots are presented. The first method involves confining all wastes and water to the feedlot area until maximum decomposition occurs. A feedlot was designed to completely eliminate runoff and percolation thus creating a solids-liquid ratio on the surface to promote rapid decomposition. The lot had a dish shaped porous surface on a sand bed with imbedded collector drains. Perforated steel matting was used for the surface. This original design did not work well as cattle wastes and hair formed a nearly impermeable layer on the sand. The use of the sand filter was abandoned but the use of the perforated steel matting proved positive. The second method involved the use of a minimum area for the feedlot to favor decomposition and treatment of wastes. A system of diversion ditches and drying terraces was used to handle runoff and wastes from a sloped lot. Sample wells were used to study groudwater flow and quality near the terraces. General groundwater quality in the vicinity of the terraces was poor, however, results indicate that the drying terraces were not the cause of the poor quality. The third method involves the return of feedlot wastes to the land at a rate that does not inhibit full crop production. Factors that must be considered include climate, wastes, soils, crops, rotations, manure nitrogen content, and cattle feed type. Due to the lack of sufficient funding only preliminary results and conclusions were made for this method. (Seigler-IPA)

17a. Descriptors
*Feed lots, *Cattle, *Farm wastes, *Water pollution sources, Terracing, Agricultural runoff, Farm management, Feeds, Livestock, Decomposing organic matter, Water pollution, Groundwater, Confinement pens, South Dakota, Fertilization.

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DEVELOPMENT OF ANIMAL WASTE FACILITIES FOR MINIMIZING WATER POLLUTION

Introduction

Much attention has been focused on protecting water from human and animal sources of pollution. In states similar to South Dakota, animal pollutants may be potentially a much greater hazard to surface and ground water than are human sources of pollutants. For this reason much consideration has been directed towards methods to control pollution from animal sources in South Dakota.

Project A-025-SDAK made an assessment of the pollution potential of runoff from production livestock feeding operations. It determined that the removal of solids from the runoff would reduce the pollution potential for most constituents by about 35%. It also concluded that over 5% of the total waste generated on a lot was removed with surface runoff therefore leaving approximately 95% of the total waste produced to be removed either by cleaning operations or to be decomposed on the feedlot surface. The purpose of this research has been to supply needed information to control the pollution caused by the surface runoff and that caused by the waste which was removed by cleaning operations.

There are several alternatives available to the feedlot operator for disposing of waste. This research, which is divided into three distinct parts, addresses a particular process for a distinct different alternative. It includes (a) a method associated with confining all wastes and water to the feedlot area until maximum decomposition occurs, (b) a method where a minimum area is used which will favor a considerable amount of decomposition and treatment and (c) the return of waste to

the land at a rate which will not inhibit full crop production. This research is not all encompassing in these areas and does not address the several other alternatives such as recycling the waste through the animals or the manufacture of a saleable by-product.

PART A. CONFINING WASTE AND WATER TO THE LOT DURING DECOMPOSITION

The original objective of this phase of the project was to completely eliminate runoff, precolation of water to the deep substrata under the lot and to create a solids-liquid ratio of wastes on the surface which would enhance rapid decomposition. This was to be accomplished for the feedlot area by utilizing a dish shaped porous surface on a sand bed with imbedded collector drains. The porous surface was to be created by placing World War II surplus landing mat over the sand surface. If this mat proved successful, similar type steel surfaces could be manufactured for this express purpose. The imbedded collector drains were to drain into an adjacent holding pond.

Procedure

The facility was constructed and tested adjacent to a conventional unpaved feedlot. A feeder, the Dakota Eastern Feedlot, Ltd. (DEFL), cooperated by providing the conventional feeding and cattle management operation.

Accepted management practices relative to cattle, materials handling and feeding practices were utilized in the project. Four pens, each with a capacity for 100 animals, were constructed on a surface designed to have sufficient capacity including manure accumulation to control a 10 year, 24 hour reoccurrence rainstorm. One type of porous surface, a perforated steel matting, was selected for the lot design. The surface configuration prevented runoff from the area with the porous surface allowing percolation of the moisture into the sand bed. The base of the sand bed was sealed to prevent deep percolation and act as a

filter. Collector drains discharged the collected filtered water into a holding pond until field disposal could be completed. The selected porous surface must be acceptable for the cattle, be easily cleaned and still have a degree of permanency.

Standard weather observation equipment was available to determine the environmental conditions encountered. Solids were removed from the feedlot at the discretion of the operator for field disposal or temporary storage depending on pollution potential at the time of removal. Besides the determination of the quality and quantity of runoff from the unit, observations were to be made on animal behavior on the surface, animal performance, acceptability with respect to feeding and cleaning operations, durability of the unit, possible feed losses, fly and insect problems as well as odor nuisances. Other allied uses for the selected steel surface were also observed.

Constructed Facilities

A facility (Figure 1) was constructed on the Dakota Eastern Feedlot, Ltd. (DEFL) located near Elk Point, South Dakota. The surface utilized was perforated steel platform (PSP) used for temporary landing strips by the military. (Since this time a similar platform referred to as Perf-A-Lot is availabile commercially.) High costs and operational efficiency prevented installation of original plans designed for statistical analysis of results. The final construction included an area 250 feet by 80 feet covered with PSP. The area was divided into four pens of equal size. The feedlot area was excavated and filled with 24 inches of sand and then overlaid with PSP. The sand bed (particles smaller than 149 microns removed) was shaped to create an eight inch

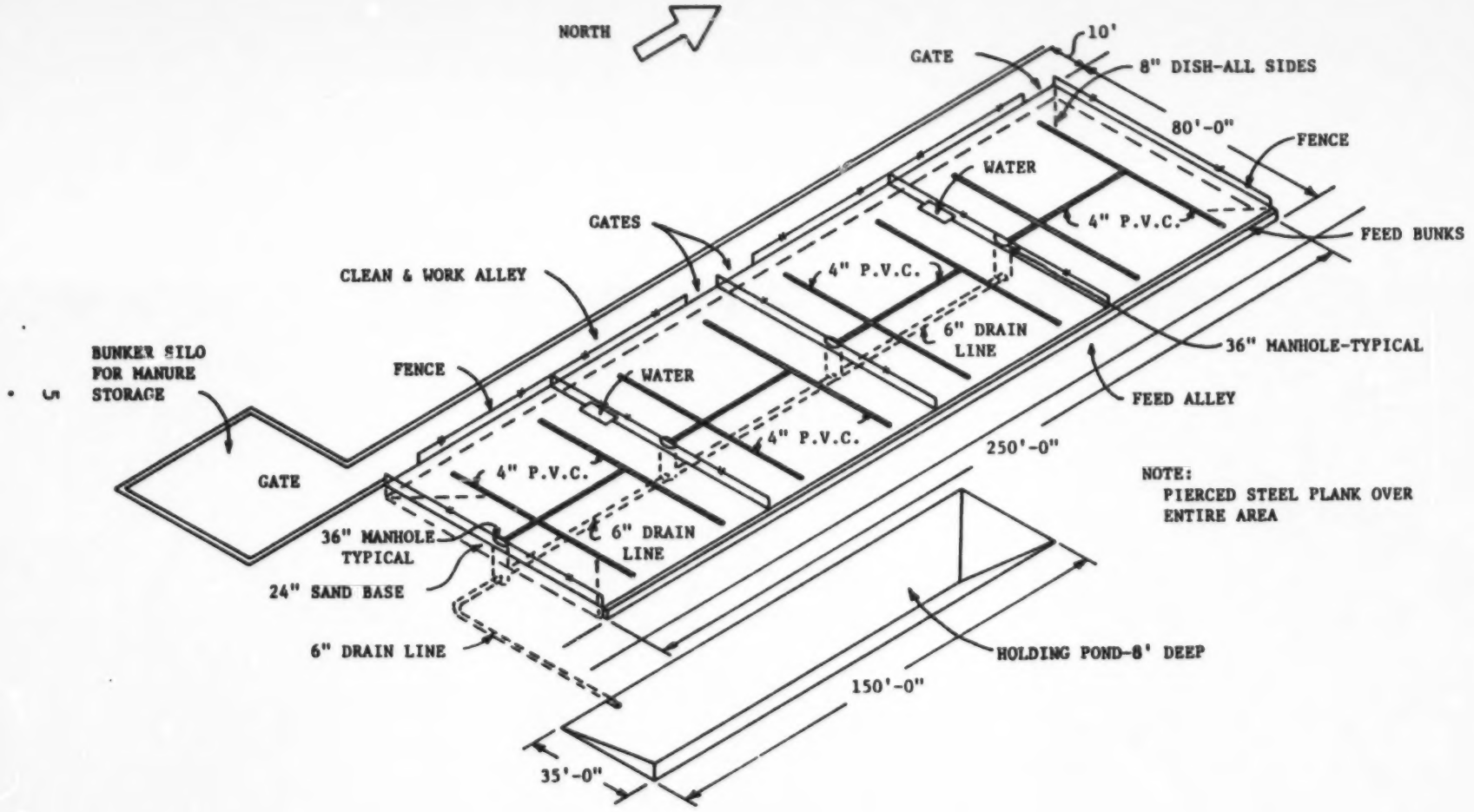


FIGURE 1. Schematic of constructed facility

Figure 2. Platform material used to form a porous surface.

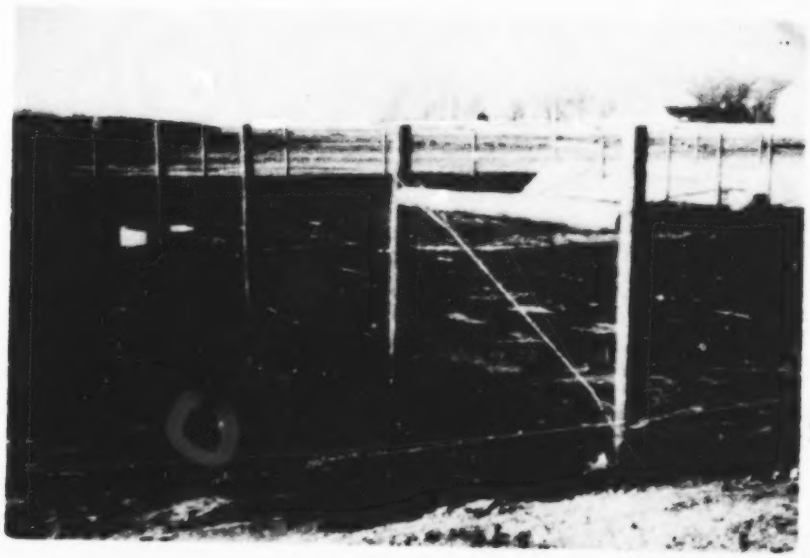


Figure 3. Lot under construction. The seal has been placed on the excavated area in readiness for the sand bed.

Figure 4. Completed lot.

Figure 5. Cattle immediately after being place in lot.

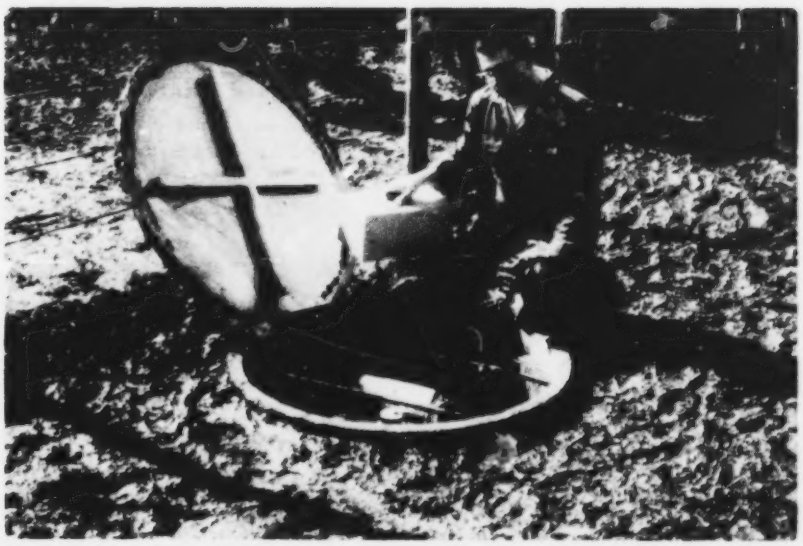


Figure 6. A manhole in each lot served as collection point for filtered water. Instrumentation was housed in the manhole.

dish in the center of the 20,000 square foot area. An asphalt seal was spread on the sides and bottom of the excavation. Foreign water was diverted away from the feedlot. A six inch drain series connected four 36 inch manholes providing drainage of the system to a 150 x 35 x 8 foot holding pond. The base of the holding pond was also asphalt sealed.

System Operation and Measurements

One hundred animals per pen (about 50 square feet per animal unit) were placed on the lot in January. Apprehension about cattle adapting to the steel surface was non-founded. Although their first steps were taken cautiously, the cattle did not slip or slide. Within minutes the cattle were at complete ease. The surface was satisfactory in all respects. The manure remained unfrozen, became dry and could have been removed at any time the operator desired. A two inch rainfall occurred over a two day period on February 18 and 19. Figure 8 illustrates the condition of the lot after the first day's rain which amounted to 0.4". Runoff quantities were not obtained. Figure 9 shows the appearance of the lot on February 19 after a total of 2 inches of rainfall. Analytical results of samples obtained from the filled holding pond showed that a portion of the liquids filtered through the sand. Therefore, it is concluded that for this rainfall event, the drain system functioned. Figure 10 shows the feedlot being cleaned three weeks after the rainstorm. The lot had dried sufficiently to permit cleaning and the livestock were relatively clean.

Flow measuring equipment was installed in the manholes at this time. On March 19 five inches of snow fell on the lot. Figure 11

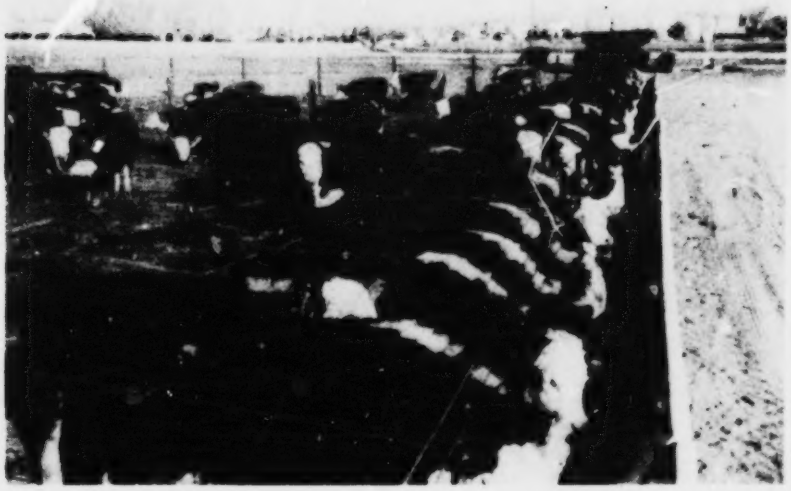


Figure 7. Lot a few days after animals were introduced.

Figure 8. Condition of lot on Feb. 18, 1971 after 0.4 inches of rain.

Figure 9. Appearance of lot on Feb. 19, 1971 after the two inches of rain.

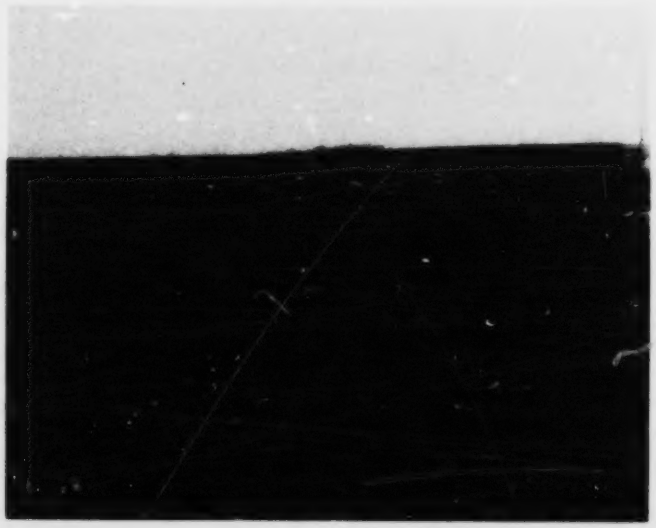


Figure 10. Condition of lot on March 5, 1971 during a cleaning operation.

Figure 11. Condition on March 20, 1971, one day after a 5" snowfall.

Figure 12. After the one inch rainfall of April 21, 1971.

depicts the condition the next day. On April 21 a one inch rainstorm fell (Figure 12). The lot dried very little between these two precipitation events. The quantity of runoff through the sand bed was less than one half gallon per minute and generally below the measuring capacity of the equipment. The logical and true conclusion was reached that the sand filter was plugged.

Drain Modification

A laboratory model was constructed to determine what had happened. A scale model of the system was developed. Without manure, the drain handled large quantities of water. As soon as material was applied, (actually a slurry after the cattle stirred it up) the infiltration rate was sharply reduced and soon a thin layer of the material accumulated next to the sand surface (Figure 13). A layer as shallow as one tenth of an inch thick would reduce infiltration to less than one tenth inch per hour. As the layer thickened, the rate approached that of capillarity movement. A closer examination of the material indicated that hair was a perdominant ingredient. The PSP surface prevented this layer from being disturbed by the hooves of cattle and a nearly permanent seal formed. The sand bed filter was abandoned.

A subsequent filter (Figures 14 and 15) was model tested and installed. The model indicates the actual cross section dimension. A prototype was installed at two locations in the fence line between the two north pens and between the two south pens (Figure 1) at the low point of the PSP surface with the runoff material entering the filter on the sloping sides. The material within the filter was pea rock sized gravel. Further modification included a cover over the filter and

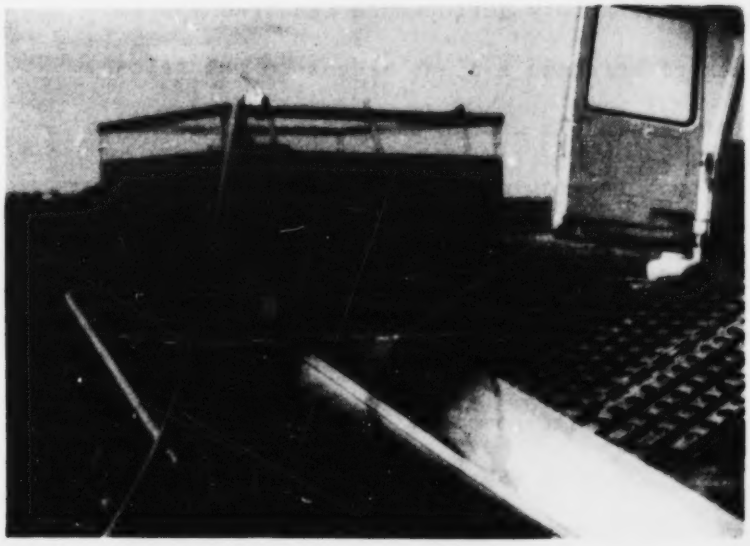


Figure 13. A model of original system.

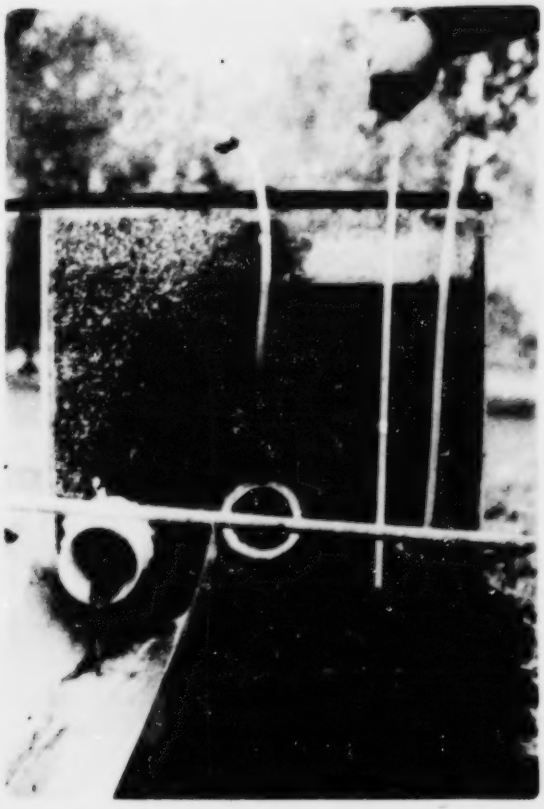


Figure 14. Model of the modified filter system.

Figure 15. Installation of the modified filter system.

changes in the gravel center. The drain performed satisfactorily during the summer and fall. However, satisfactory performance required approximately two hours labor per week to maintain a clear access to the filter surface. Also the drain is limited in the amount of solids that it can handle. It is recommended that the maximum accumulation of manure on the feedlot surface be limited to 30 days.

In the next spring the drain was further modified due to an organic "jelly-like" accumulation in the gravel filter material which plugged the filter. The modification consisted of removing the gravel and covering the sloping surface with a screen that could be hosed clean in the event of plugging. This filter performed satisfactorily during the summer and fall; however, it had the same labor requirements previously mentioned.

Observations would indicate that the filter would be much more efficient and maintenance free if they were placed on a lot sloped away from the feed bunk area toward a waste collection point outside the feedlot area. Hydraulic settling of solids could be obtained and the manure would be removed from the resting and feeding area. The design, however, was not pursued for two reasons: first, the amount of labor involved in reshaping the surface and replacing the PSP surface would be unrealistic and secondly, the required placement would not serve the original purpose of the drain. A sloped lot has other methods which satisfactorily separate the liquids and solids which are superior to this method. It was concluded at this point that the dish shaped, porous surface lot concept was not a satisfactory solution for pollution control or animal management.

Several production feedlots have made application of the PSP surface since its introduction on the research site. Because of the demonstrated sealing of the filter surface, the dished concept has not been used. Generally the application has been to have the surface slope away from the feed bunk to a waste collection and handling area outside the pen area.

Other Uses of PSP in Feeding Operations

The management practice for pollution control on unpaved sloping lots utilizes the principle of hydraulic control of velocity to allow solids to settle and the liquid is stored in a holding pond. Removing the settled solids from the shallow collection ditch (debris basin) must be completed periodically. The ditch remains soft for extended periods of time and maintenance must be timed to climatic conditions. Figure 16 illustrates PSP used in such a ditch. This channel carries the runoff from a four acre sloped unpaved lot. The sediments settled to the channel bottom with relatively clear water entering a treatment lagoon. Sediments several inches deep are cleared from the ditch with conventional front end tractor loaders without difficulty.

A practice of using individual portable hog sheds for farrowing and initial feeding of feeder pigs oftentimes encounter a mud condition creating a disease hazard and a potential pollution. Figure 17 illustrates the use made of PSP. The perforations were not a deterrent to animal movement. A relatively dry desirable surface is available which can be readily cleaned. The surface is easily moved when the sheds are relocated.

Other uses in farmstead problem areas can also be alleviated with

Figure 16. Perforated Steel Platform used for stabilizing a debris ditch.

Figure 17. Non-stabilized hog operations often need stabilized surfaces.

this type surface; areas around watering fountains, adjacent to feed bunks in unpaved lots, temporary creek crossings.

Observations and Conclusions

The original concept and design of a dish shaped feedlot with a porous surface on a sand bed to partially treat the liquids which had been separated from the solids did not prove to be satisfactory. Waste material from the cattle, combined with hair, forms a nearly impermeable layer on the sand bed if it is not disturbed by the cattle. The pierced steel platform protects this layer to that principal vertical movement of liquid was due to capillarity. This rate is not sufficient to protect the lot during rain and snow storms.

A number of observations were made relative to the use of a pierced steel surface for paving a problem area. (1) Animals adapt readily to the surface without difficulty. (2) The surface remains relatively stable without indentations or humps forming with time. (3) The surface is readily cleaned with power equipment with some attention needed in regard to direction of channels and tractor movement. (4) The fear of aggravating a fly problem due to feed falling into the perforations is non-founded. (5) Although observations were made over only a limited period, the material showed no signs of deterioration due to corrosion or mechanical damage. (6) Cleaning operations could be carried out when concrete lots remained frozen. (7) Under certain conditions during the warm season the lots were cooler than other paved lots. (8) During dry seasons the surface is nearly dust free. (9) A lot can be remodeled with relative ease because sections as large as 80 feet by 32 feet can be dragged on and off an area with tractors

normally available for normal farm operations.

The economics of a pierced steel platform surface applied to a normal sloped lot compared to other types of paved surfaces will vary with the locality, design, and requirement for a specific installation. Availability of materials for concrete, equipment on hand for forming surfaces, labor costs, and shipping distances enter into an analyses. Possibility of revamping a lot at a later date is also a consideration.

PART B. MINIMUM AREAL USE

The cattle feedlot is considered by some as one of the largest reservoirs for contaminants able to reach surface bodies of waters. A feedlot can be generally described as an enclosed area where cattle are concentrated for the purpose of preslaughter fattening. Animals may also be concentrated into small areas similar to feedlots for preshipment storage or for wintering operations. Common characteristics of feedlots are a land area void of viable plant life, large numbers of animals, a high concentration of waste material, and esthetic problems caused by the general conditions associated with a feedlot.

Sanitary hazards caused by the accumulation of feedlot wastes can be in the form of fly breeding, odors, dust, animal health, or potential water pollution. Many of the above factors may be controlled by proper management of the solid portion of feedlot wastes and by proper management of the runoff originating on and flowing over the feedlot surface. The solid portion may be removed by cleaning operations.

A treatment system designed to treat the runoff from a feedlot should be designed in accordance with three basic features: (a) slope the feedlot so as to control runoff originating on the lot surface and to direct the runoff in the desired direction; (b) provide a diversion channel to transport the runoff to storage areas and allow solids in the runoff to settle; and (c) design basins to hold the runoff for a suitable period of time until the water can be applied to the land.

A feedlot pollution control facility was put into operation in October, 1971, at the South Dakota State University campus in order

to control the runoff from the Beef Breeding Unit (BBU) located on the northern edge of the campus. The system at the BBU employed a diversion ditch and drying terraces. The ditch acted as a collector channel to carry the runoff originating at the BBU to the drying terraces. The channel was also to serve as a debris basin where the velocity of the runoff could be slowed and the solids allowed to settle. Drying terraces, receiving the discharge from the diversion ditch, acted as a combination holding pond and evaporation pond. Runoff was held in the terraces until the water in the runoff evaporated into the atmosphere or possibly entered the soil system surrounding the terraces. In addition to the pollution control afforded by the diversion channel and drying terraces, the BBU continued its cleaning operations that were conducted in the early summer to manage the solid portion of the wastes produced at the feedlot.

The original purpose of initiating the construction of the diversion channel and drying terraces was esthetic in nature. Originally, the runoff was allowed to drain to the ditch north of the BBU, adjacent to the old Highway 77; and motorists travelling in this area were often offended by the resulting conditions. In order to solve this problem the diversion channel and drying terraces were built to divert the runoff from the BBU away from the highway. The terraces held the runoff from the BBU until the water evaporated or percolated through the soil. Although drying terraces, in general, prevent runoff from directly entering surface bodies of water, the terraces could not be deemed successful if they in turn polluted the groundwater in the vicinity. The general objective of the study was to evaluate the effect of the

Fig. 18. Aerial photograph of the northern edge of the South Dakota State University campus in 1969 showing the general area of the investigation.

terraces on the groundwater quality in the vicinity of the BBU. The more specific objectives of the study were to determine:

(a) The direction of groundwater flow in the vicinity of the terraces;

(b) The proper location for placement of sampling and control wells to evaluate the effect of the terraces on the groundwater in the vicinity; and

(c) The extent of groundwater quality changes in the vicinity of the terraces.

Little was known concerning the soil conditions in the vicinity of the terraces, the type of aquifer that would be encountered in the area, the effects of other possible sources of groundwater contamination in the vicinity of the terraces, and the groundwater quality prior to the installation of the terraces. For these reasons, it was recognized that the objectives of the study might not be achieved.

Investigation Site

The drying terrace treatment system was constructed on the northern edge of the South Dakota State University campus. Figure 18 shows an aerial photograph of the area in 1969, prior to the installation of the terrace system, with east being at the top of the photograph. The location of the terraces is represented by the blacked out portion of Figure 18. The site of the terrace system is bordered on the east by the Beef Breeding Unit (BBU) and Old Highway 77, on the north by coal piles and the Highway 14 by-pass, and on the west by Six Mile Creek. The slope of the general area was toward Six Mile Creek. At the beginning of the study, the assumption was made that the groundwater flowed in accordance with the slope of the land, that is, the groundwater in the vicinity of the terraces flowed toward Six Mile Creek. This assumption

aided in the placement of wells for this study.

Many points of potential groundwater contamination are located in the immediate vicinity of the terraces. Figure 19 shows the location of these points with respect to the terraces. From the figure it can be seen that groundwater quality changes in the area could be introduced by the BBU, the coal storage and old refuse disposal area, and the horse stables, in addition to the terraces. The coal storage and old refuse disposal area presented special problems in that a large ash pit is located in the immediate vicinity of well #5.

The terraces functioned in a manner inconsistent with their design. The terraces were designed so that the runoff from the BBU would enter Terrace 1; the overflow from terrace 1 would enter terrace 2; and the overflow from terrace 2 would enter terrace 3. During the study, however, the conditions observed at the terraces did not occur as described above. Terraces 1 and 3 contained water throughout the summer of 1972. Terrace 2 held water only one to two days after a runoff event of sufficient magnitude to produce an overflow from terrace 1. After this time terrace 2 remained empty.

During the construction of terrace 2 an old tile drain was intercepted. Seepage through the tile drain could have caused terrace 2 to empty in the manner described above. Because the tile drain was located on the north edge of terrace 2, the seepage apparently could have entered the coal storage and old refuse disposal area. Several attempts have been made to seal the tile intrusion with a concrete plug; however, insepction of the site indicated that the plugs had been washed away.

The condition of the terraces in May, 1973, is shown in Figure 20. The photographs were taken from one of the coal piles located directly

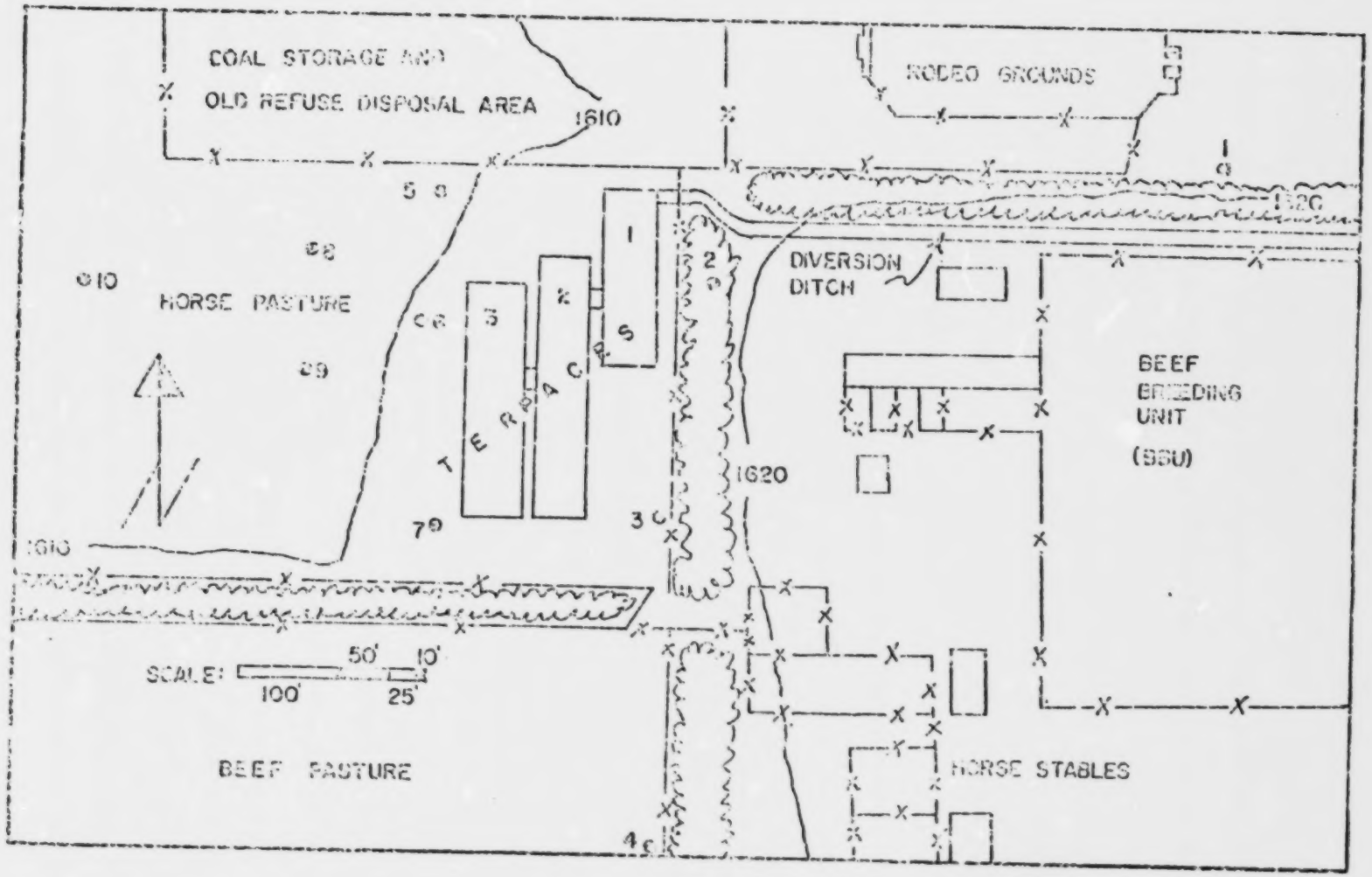


Fig. 19. Map of area surrounding the drying terraces showing potential points of groundwater contamination, ground elevations, and test wells.

Terrace 1

Terraces 2 & 3

Fig. 20. Photographs of drying terraces at the Beef Breeding Unit, May, 1973.

north of the terraces. Terraces 1 and 2, in this figure, are shown as they were much of the time during the summer of 1972. The dry conditions persistently present at terrace 2 allowed a heavy cover of grass to develop in comparison with terrace 1. Terrace 3 did not contain water when the photograph was taken; however, throughout the summer of 1972, the south half, if not the entire bottom area of the terrace, contained water. A depression outside the southwest corner of terrace 3 also remained consistently moist throughout the summer of 1972. The dead vegetation (brown color) in terrace 3 is the canary grass planted for the removal of plant nutrients.

The terraces were constructed in the east end of a horse pasture. After the embankments were allowed to consolidate, the horses were allowed to graze in and around the terraces. In Figure 20, two horses are photographed grazing in terrace 3.

Well Point Information

Sampling wells were drilled for the dual purposes of determining the direction of flow and potential groundwater quality changes in the vicinity of the terraces. The location of the 10 sampling wells drilled for this study is shown on Figure 19. Wells 1, 2, 3, and 4 were drilled for the purpose of being control wells; while wells 5 through 10 were drilled primarily to monitor the potential groundwater changes in the immediate vicinity of the terraces.

The wells were drilled with a drilling rig using a three-inch auger with depths from 11 to 20 feet deep. After the hole for the well had been drilled, a galvanized pipe with a 30- or 36-inch sand point was inserted into the well hole. A length of pipe approximately

1 1/2 feet long was allowed to protrude above the ground. After the well points had been inserted, a graded rock, called pea rock, was poured around the well point to a depth of approximately 10 feet.

Clay and other undesirable material clogged the sand points of most of the wells so as to make them unproductive, necessitating the development of the wells. To develop the wells, air and water were forced into the well points. This process removed the clay from the sand points. Even after the development, because of the nature of the soil, the recharge of the wells was slow and for this reason the yield from all ten wells was poor. The more productive wells yielded only approximately one gallon of water when pumped daily. Most of the wells were drilled into a very cohesive soil; however, a small-grained sand was encountered at the site for well 10. A cohesive soil yields water slowly, making recharge negligible over a short period of time.

The groundwater elevations were determined by measuring the distance from the well opening to the water table with a measuring stick and correcting for the length of protruding pipe. Reference for these measurements was the adjacent ground surface. This method of reference was employed because the wells were not placed in concrete and settlement could possibly occur. By using the ground elevation as the base elevation the effects of settlement could be minimized.

Water table elevations were taken at the well site, usually one day before sampling. After groundwater elevations were determined, the water was purged from the well. Purging of the well was accomplished prior to sampling to remove groundwater that had been standing in the well in order to obtain a more representative sample.

Sampling and Laboratory Procedures

Quality changes of the groundwater in the vicinity of the terraces were monitored by general and specific water quality parameters. General quality parameters used in this study were pH and specific conductance. Specific parameters used in this study were selected on the basis of the contaminants present in feedlot runoff, the ease with which the constituent could be monitored, and the experiences of groundwater studies for other waste disposal methods. On the basis of the above considerations the specific parameters selected for monitoring were chlorides, total kjeldahl nitrogen and nitrates.

Groundwater samples were collected at the drying terraces from September, 1972, to March, 1973. Samples were taken approximately monthly during that period, providing six sets of data for each location. Sampling took place one day after the groundwater elevations were determined and the wells purged. Sampling was performed at this time because approximately 24 hours were needed for groundwater to enter the well point in quantities sufficient to satisfy testing requirements.

After the pH and specific conductance of the samples had been determined, the samples were transported to the laboratory of the Water Resources Institute. At this laboratory, analyses were performed on the samples for chlorides, total kjeldahl nitrogen, and nitrates. These chemical analyses were based on procedures presented in Standard Methods for the Examination of Water and Wastewater. Chlorides were determined by the Mercuric Nitrate Method.

Discussion of Results

The first priority of this study was to determine the influence

of the drying terraces on the direction of groundwater flow in the vicinity of the terraces. Figures 21 and 22 show contour lines of the groundwater elevations as determined by the elevations obtained from each well.

Figure 21 shows contour lines that represent the groundwater flow on September 2, 1972. In September, 1972, terraces 1 and 3 contained a substantial quantity of water and may have had an influence on the groundwater flow in the vicinity of the terraces. Figure 22 shows contour lines that represent the groundwater flow on March 2, 1973, as determined by the groundwater elevations on this date at the wells shown. In March, 1973, and throughout the preceding several months, the terraces did not contain water and the effect of the terraces on the groundwater in the vicinity would probably have been negligible. If lines were drawn on Figure 21 perpendicular to the contour lines, the direction of flow would appear to be in a west northwest direction from the terraces toward wells 6 and 8. If the same lines were drawn on Figure 22, the direction of flow would appear to be in a more westerly direction from the terraces than is the case in Figure 21. The direction of groundwater flow, however, remained toward wells 6 and 8. The influence of the terraces on the general direction of groundwater flow would appear to be negligible.

General Quality of Groundwater

Table 1 contains the results of laboratory tests conducted on the groundwater during this study. The mean concentrations, with the exception of pH, were found by averaging the results from the analyses for a given well. On March 3 and 4, 1973, duplicate samples were

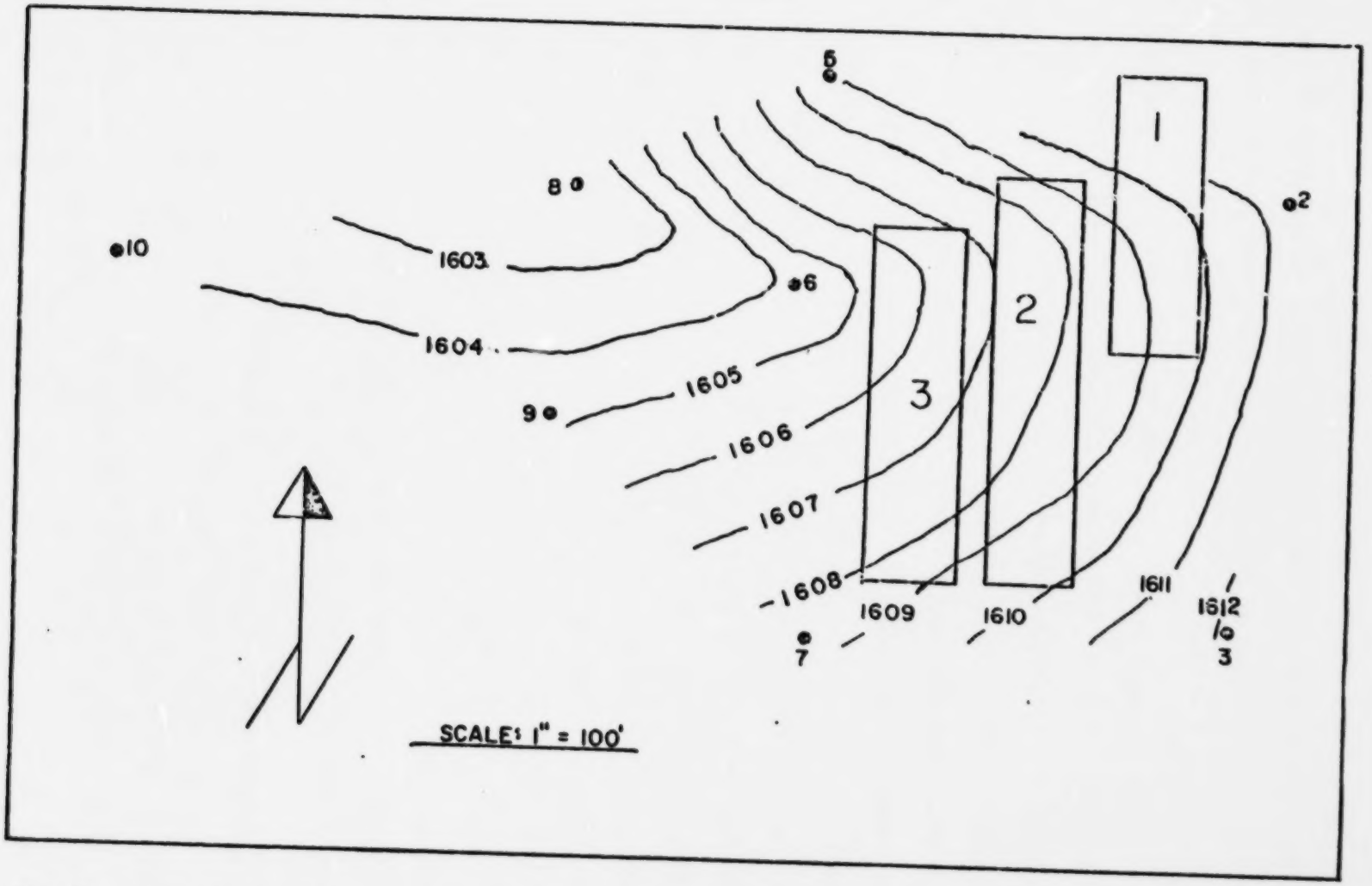


Fig. 21. Groundwater contours as determined by elevations obtained at the wells shown, September, 1972.

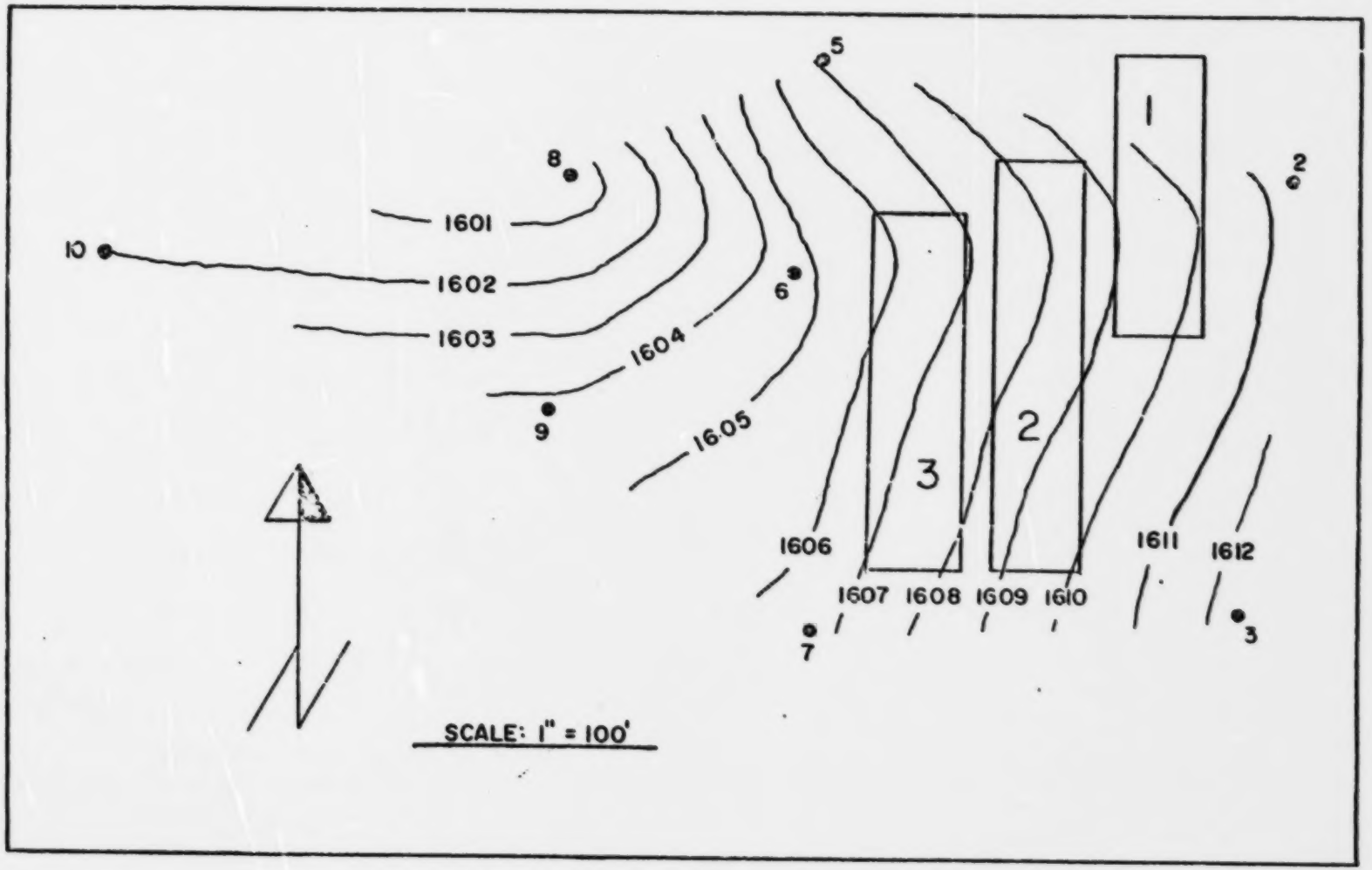


Fig. 22. Groundwater contours as determined by elevations obtained at the wells shown, March, 1973.

Table 1. Specific Conductance of Samples Collected at the Drying Terraces, μmhos/cm @ 25°C, September, 1972 - March, 1973.

Well Number	Date						
	Sept.	Oct.	Nov.	Jan.	Ave. Mar. 3 and 4	Mar. 24	Mean
1	3200	3490	3660	3240	3180	3300	3340
2	3260	3450	3140	3080	2850	2600	3060
3	2200	2090	1990	1770	1750	1900	1950
4	3720	3810	2610	3970	3820	4600	3760
5	4100	3600	3870	3920	3900	3200	3760
6	6630	6270	6690	5800	5950	6300	6280
7	13,700	15,200	15,300	17,300	15,000	16,700	15,500
8	7250	7950	8890	8360	8500	10,500	8580
9	7910	10,500	10,500	9930	9780	8800	9570
10	18,900	17,800	16,700	15,700	15,800	16,700	18,900

Table 1. Chlorides of Samples Collected at the Drying Terraces, mg/l, September, 1972 - March, 1973.

Well Number	Date						
	Sept.	Oct.	Nov.	Jan.	Ave. Mar. 3 and 4	Mar. 24	Mean
1	16.5	17.8	20.5	19.0	21.4	28.5	21.0
2	30.5	37.8	46.5	49.0	52.0	80.0	49.0
3	73.0	64.0	85.5	68.0	72.0	80.0	74.0
4	415	462	335	550	535	660	493
5	200	220	188	190	192	225	203
6	45.0	45.0	41.0	39.0	43.0	44.0	43.0
7	80.0	89.0	101	119	131	160	113
8	50.0	59.0	90.0	65.0	71.2	112	75.0
9	80.0	125	119	148	132	146	125
10	40.0	50.0	44.0	43.0	51.0	48.0	46.0

Table 1. Kjeldahl Nitrogen of Samples Collected at the Drying Terraces, mg/l, September, 1972 - March, 1973.

Well Number	Date						
	Sept.	Oct.	Nov.	Jan.	Ave. Mar. 3 and 4	Mar. 24	Mean
1	0.84	1.12	0.93	0.77	0.88	0.98	0.92
2	1.12	1.68	0.56	0.84	0.94	7.56	2.12
3	1.54	1.87	0.84	1.68	1.24	0.84	1.34
4	2.38	5.04	3.36	2.10	1.96	1.89	2.79
5	20.7	20.7	15.2	15.4	13.2	31.0	19.4
6	2.80	2.24	0.56	0.77	0.75	0.70	1.30
7	1.12	2.24	0.56	0.70	0.80	1.40	1.34
8	0.84	1.68	1.12	0.84	0.42	0.98	0.98
9	0.84	1.12	0.28	0.49	0.37	0.42	0.59
10	3.92	7.28	2.80	0.35	1.25	2.16	2.96

Table 1. Nitrates of Samples Collected at the Drying Terraces, mg/l, September, 1972 - March, 1973.

Well Number	Date						
	Sept.	Oct.	Nov.	Jan.	Ave. Mar. 3 and 4	Mar. 24	Mean
1	0.82	2.24	0.10	0.07	1.58	2.61	1.24
2	2.89	2.53	0.66	1.16	2.16	0.25	1.61
3	2.38	4.80	12.1	4.70	3.55	5.22	5.44
4	30.5	19.2	34.2	41.0	66.7	86.4	43.3
5	0.68	0.50	0.50	0.50	1.06	1.21	0.74
6	0.10	0.15	0.50	0.18	0.01	0.01	0.16
7	0.14	0.51	0.74	0.21	0.0	0.0	0.25
8	0.43	1.64	0.94	0.10	0.0	0.0	0.55
9	0.30	0.08	0.62	0.44	0.21	1.27	0.49
10	0.40	1.00	5.80	0.35	1.25	2.16	1.83

collected and duplicate laboratory analyses conducted. This procedure supplied four data points from each sampling location, which were averaged to make one data point termed the "Average of March 3 and 4". This sampling point, resulting from the four analyses performed on March 3 and 4, was averaged with the five other data points to obtain the mean values. The purpose of conducting duplicate sampling and testing was to obtain a reference for sampling and testing variations for the study. The results of these duplicate procedures is shown in Table 2.

The general quality parameters of this study were pH and specific conductance. Table 3 shows the results of pH analyses conducted on the groundwater samples. From Table 3 it can be seen that the lowest pH values obtained for each well occurred on September 10, 1972; after which time, the groundwater encountered at the wells exhibited a general increase in pH. The pH range of the groundwater studied was from 4.9 to 8.8.

A fully satisfactory explanation of the variations in pH of the groundwater at the various wells is not readily apparent. Expected biological activity in the soil and terrace system and the associated production of carbon dioxide may have been an influencing factor. The increase in pH was largest at wells 3 and 8; however, most wells exhibited substantial pH changes and there does not seem to be a pattern in pH variations that could be attributed to the influence of the drying terraces.

A review of the data in Table 1 would reveal that the groundwater in the vicinity of the terraces had a specific conductance range between 1900 and 17,000 μmhos/cm @ 25°C. Specific conductance of the groundwater from the individual sampling wells remained relatively

Table 2. Results of Analyses of Samples Collected at Wells in the Vicinity of the Drying Terraces on March 3, 1973.

Well Number	Trial	Parameter: Specific Conductance μmhos/cm @ 25°C	pH units	Chlorides mg/l	Kjeldahl Nitrogen mg/l	Nitrates mg/l
1	1	3400	6.90	20.0	1.12	0.63
	2	3200	7.06	20.5	1.12	0.45
2	1	2800	7.00	48.0	0.98	1.86
	2	3000	7.10	51.0	0.70	1.62
3	1	1600	8.10	74.0	1.26	2.35
	2	1600	8.30	72.0	1.26	1.40
4	1	3700	7.30	530	2.10	46.4
	2	3800	7.30	530	2.10	44.4
5	1	4000	7.10	195	12.6	0.62
	2	3400	7.10	195	12.6	0.58
6	1	5800	8.80	42.0	0.70	0.0
	2	5800	8.80	42.0	0.84	0.0
7	1	13,600	8.60	122	0.84	0.0
	2	13,600	8.60	125	1.12	0 0
8	1	8400	8.50	70.0	0.42	0.0
	2	8300	8.60	70.0	0.56	0.0
9	1	10,500	7.20	125	0.42	0.0
	2	9,000	7.20	125	0.56	0.0
10	1	15,700	7.30	52.0	2.66	0.97
	2	--	--	52.0	2.94	0.89

Table 2. Results of Analyses of Samples Collected at Wells in the Vicinity of the Drying Terraces on March 4, 1973.

Well Number	Trial	Parameter: Specific Conductance μmhos/cm @ 25°C	pH units	Chlorides mg/l	Kjeldahl Nitrogen mg/l	Nitrates mg/l
1	1	3200	7.25	22.5	0.56	2.61
	2	2900	7.20	22.5	0.70	2.61
2	1	3000	7.20	54.0	0.98	2.52
	2	3000	7.20	55.0	1.12	2.62
3	1	1900	7.55	70.0	1.12	5.02
	2	1900	7.55	72.0	1.26	5.42
4	1	3900	7.30	540	1.82	86.4
	2	3900	7.35	540	1.82	89.6
5	1	4100	7.10	190	14.6	1.54
	2	4100	7.10	190	13.2	1.48
6	1	6100	8.00	44.0	0.70	0.0
	2	6100	7.90	44.0	0.0	0.04
7	1	16,500	8.25	138	1.12	0.0
	2	16,500	8.25	138	0.14	0.0
8	1	8600	7.95	72.5	0.56	0.0
	2	8700	8.00	72.5	0.14	0.0
9	1	9700	7.50	138	0.14	0.44
	2	9900	7.60	138	0.0	0.40
10	1	16,000	7.40	50.0	3.08	1.48
	2	--	--	50.0	3.08	1.66

Table 3. The pH of Samples Collected at the Drying Terraces, September, 1972—March, 1973.

Well Number	pH (units)					
	Sept.	Oct.	Nov.	Jan.	Mar. 3	Mar. 24
1	5.20	6.90	6.70	7.25	6.90	7.15
2	4.90	6.90	7.25	7.20	7.00	7.05
3	5.50	7.20	7.80	8.50	8.10	7.60
4	5.55	7.50	7.35	7.45	7.30	7.20
5	5.45	7.50	7.15	7.30	7.10	7.15
6	5.25	6.90	7.75	8.10	8.80	7.80
7	6.45	8.40	8.50	8.45	8.60	8.40
8	5.60	7.50	8.30	8.40	8.50	8.25
9	5.70	7.70	7.25	7.45	7.20	7.45
10	5.80	7.35	6.90	7.50	7.30	7.55

constant throughout the study.

Figure 23 shows the general quality of the groundwater at the 10 wells as measured by mean specific conductance. It can be seen that well 3 encountered the best quality groundwater when using specific conductance as a guideline and well 10 is shown to have encountered a more highly mineralized water. Figure 23 also illustrates that the control wells 1, 2, 3, and 4 encountered a better quality water than did the wells in the immediate vicinity of the terraces. Using specific conductance as a measure of the dissolved solids, wells 7 and 10 locate groundwater with the greatest amount of dissolved material and these wells could be considered the most chemically contaminated. With the possible exception of well 3, the general quality of the groundwater with respect to specific conductance in the vicinity of the terraces could be considered poor; and for the most part, would be considered unsatisfactory for such agricultural uses as irrigation.

On July 2, 1973, laboratory analyses were performed on water in terrace 1 resulting from runoff originating at the BBU on July 1, 1973. The results of these analyses were as follows: the pH was 7.70; the specific conductance was 2560 μmhos/cm @ 25°C; and the chloride concentration was 435 mg/l. The pH of the runoff in terrace 1 was in the same general range as that of the water sampled at the wells. The specific conductance of the terrace water was lower than that of the groundwater sampled at the wells; with the exception of well 3, which encountered groundwater with a mean specific conductance of 1950 μmhos/cm @ 25°C for the study. The color of the sample collected at the terrace was dark brown. The only groundwater encountered which had any discoloration that was not caused by silt was sampled at well 5. This water was

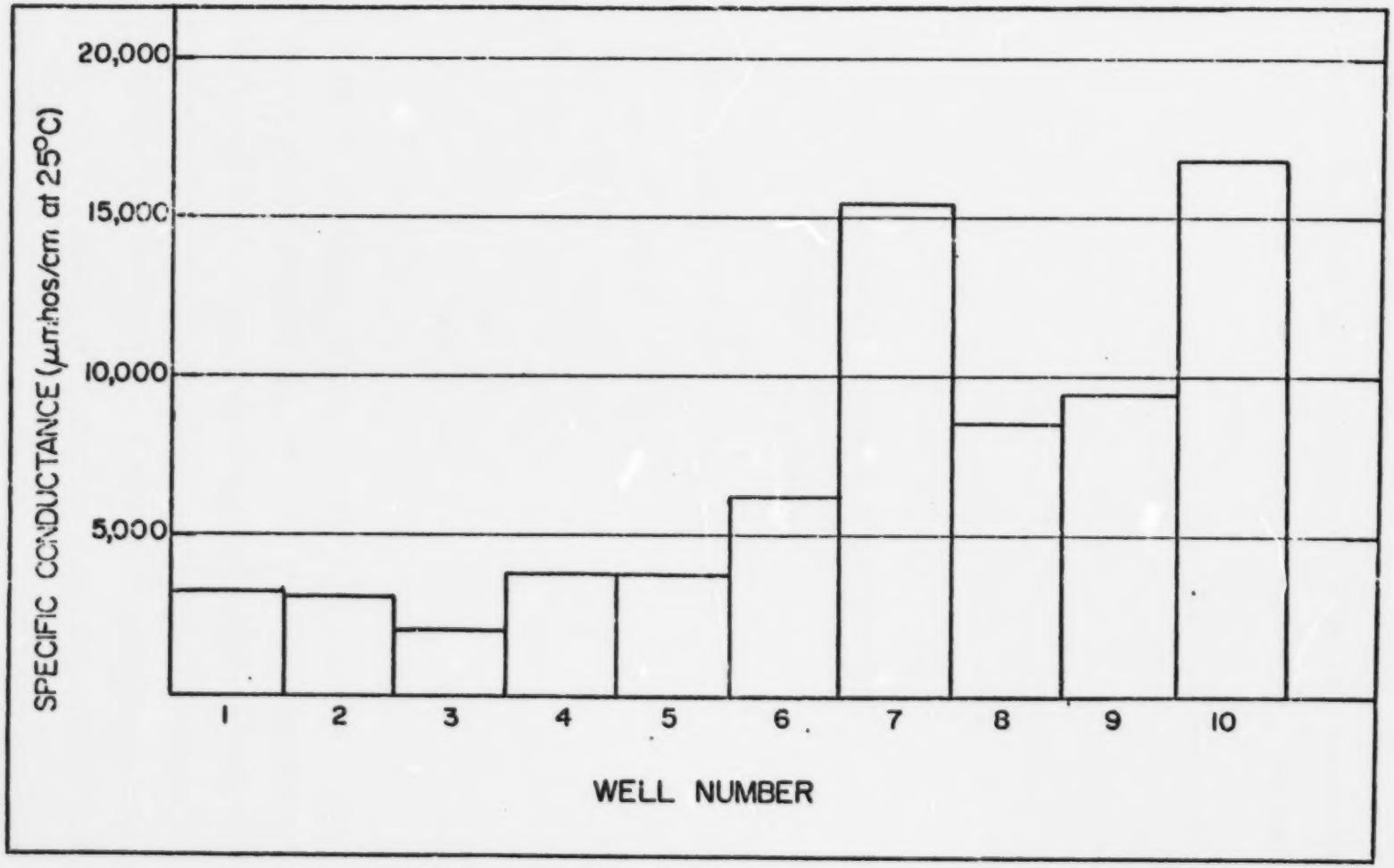


Fig. 23. Mean specific conductance at the individual wells.

yellow in color. From the above information, it would appear that the groundwater sampled at the wells was of a different general quality than that water sampled at the terrace.

Specific Quality of Groundwater

Specific quality of the groundwater studied was measured by using the chemical parameters: chlorides, total kjeldahl nitrogen, and nitrates. Monitoring of the runoff entering the terraces was performed by personnel of the Water Resources Institute and a partial list of the analytical results is shown in Table 4.

Table 4. Results of analyses of samples collected at the drying terraces, 1972 and 1973.

Date and terrace number	Parameter				
	Total kjeldahl nitrogen mg/l	BOD mg/l	COD mg/l	pH units	Total solids mg/l
June, 1972					
Terrace 1	83.0	646	1100	8.25	2700
Terrace 2	9.0	24.0	139	8.70	932
Terrace 3	2.9	14.1	29	8.72	1084
March, 1973					
Terrace 1	367	1700	6360	8.32	9448
Terrace 2	347	1180	5440	8.31	8844

Table 4 allows several points to be made concerning the performance of the terraces. The June, 1972, sample results show a decrease in chemical contaminants from the first to the third terrace. This information would indicate that the terraces were affording some type of treatment to attain a reduction in kjeldahl nitrogen, BOD, and COD from the first terrace to the third. From June, 1972, to March, 1973, the kjeldahl nitrogen, BOD, and COD concentrations of the water

sampled in the terraces increased substantially. Also, the results from the March sample indicate that the water in terraces 1 and 2 was of a comparatively uniform quality; as the samples collected in terraces 1 and 2 in March, 1973, do not vary in chemical constituents as do those samples collected in June, 1972, from terraces 1 and 2. The much higher concentrations of dissolved solids in the terraces during March, 1973, as compared to the previous year would tend to indicate that evaporation was concentrating the dissolved solids. Also, the differing solids results could be attributed to differing runoff events having varying chemical characteristics.

The chloride concentration of the water in the terraces on July 2, 1973, was 435 mg/l. Although well 4 encountered groundwater averaging 493 mg/l of chloride during the period of study, none of the wells in the immediate vicinity of the terraces encountered groundwater with an excessively high chloride content as was the case of the water sampled in terrace 1. A possible reason for the above results is that the July, 1973, runoff event was not representative and may have been a runoff event with a high chloride concentration in comparison with other runoff events. Also, if the chlorides travelled to the wells from the terraces, via the groundwater, the chlorides could have been diluted.

Isoconcentration lines are used in groundwater studies to interpret the movement of a particular contaminant or parameter. These lines represent bands of groundwater containing an equal concentration of a particular contaminant. Figure 24 shows the isoconcentrational lines of mean chloride concentrations of the groundwater in the vicinity of the terraces as was indicated by values from the individual wells.

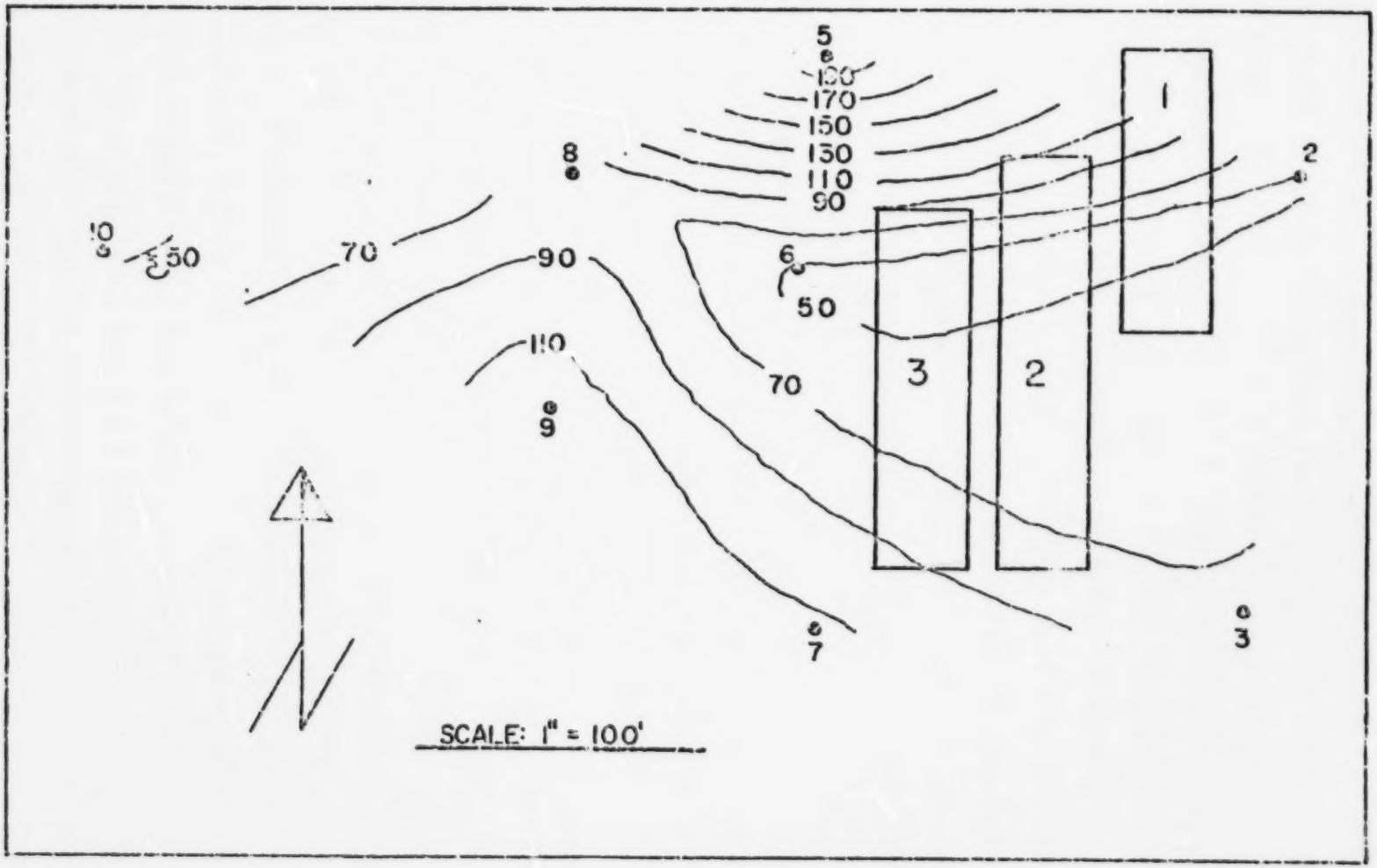


Fig. 24. Isoconcentrational lines of mean chloride values as were obtained from the sampling wells in the vicinity of the drying terraces.

The groundwater at well 5 is exceptionally high in chlorides, and as will be shown, in kjeldahl nitrogen, in comparison with other wells in the immediate vicinity of the terraces.

During the course of the investigation it was determined that a large ash pit was located in the immediate vicinity of well 5. Although it cannot be proven by the results obtained in this study, the possibility exists that the higher chloride concentrations shown around well 5 may be more localized than is represented and may be the result of the ash pit. The areal extent of the high chloride concentrations could be more clearly defined with additional sampling wells in the vicinity of well 5.

As previously indicated, the general direction of groundwater movement from the terraces is toward wells 6 and 8. Chloride analyses do not show results that indicate that the water seeping from the terraces was sampled at wells 8 and, in particular, 6. Well 6, located near terrace 3, had a relatively low groundwater elevation and encountered groundwater with a relatively low chloride content. The chloride concentrations and isoconcentrational lines obtained from wells 5, 6, and 8 would tend to indicate that the runoff treated by the terraces is seeping from the terraces and travelling in a direction toward well 5 almost exclusively. This observation would emphasize the contention that the tile drain and ash pits are seriously impairing the operation of the terraces by deleteriously affecting the groundwater in the vicinity of well 5. Taken alone, the results shown in Figure 24 might be interpreted as indicating the terraces were actually improving the groundwater quality in the vicinity with respect to chlorides. This interpretation would not seem to be valid, however, as the chloride

concentration in terrace 1 was 435 mg/l in July, 1973.

Figure 25 portrays the mean chemical concentrations of chlorides, kjeldahl nitrogen, and nitrates at the individual wells. The interpretation of Figure 25 illustrates the problems encountered when conducting a groundwater study in an area where many potential points of groundwater contamination are located, in addition to the facility being studied. Well 4, located near the horse stables, was placed in an area outside the influence of the terraces. The water in this well is the highest in chlorides and, by a factor of eight, is the highest in nitrates. The groundwater sampled at well 6, located in what was thought to be the nucleus of the terraces' activity on the groundwater, had better quality with respect to the chemical constituents tested than did most of the control wells. Wide variations in the three specific constituents among the control wells was apparent.

Kjeldahl nitrogen and chlorides were thought to be the better indicators of groundwater contamination caused by the terraces. Well 5 encountered groundwater containing high concentrations of chemical constituents common to the runoff from the BBU; while substantially lower concentrations were found at other sites in the immediate vicinity of the terraces. Two factors could have led to this result. One factor is the presence of the tile which drains the north end of terrace 2, possibly allowing the water from terrace 2 to seep into the groundwater table in the vicinity of well 5. Also, the ash pit located in the vicinity of well 5 could have received water seeping from the surface, the terraces, and/or the tile drain. Consequently, the water encountered at well 5 is perhaps the water influenced by the ash pits.

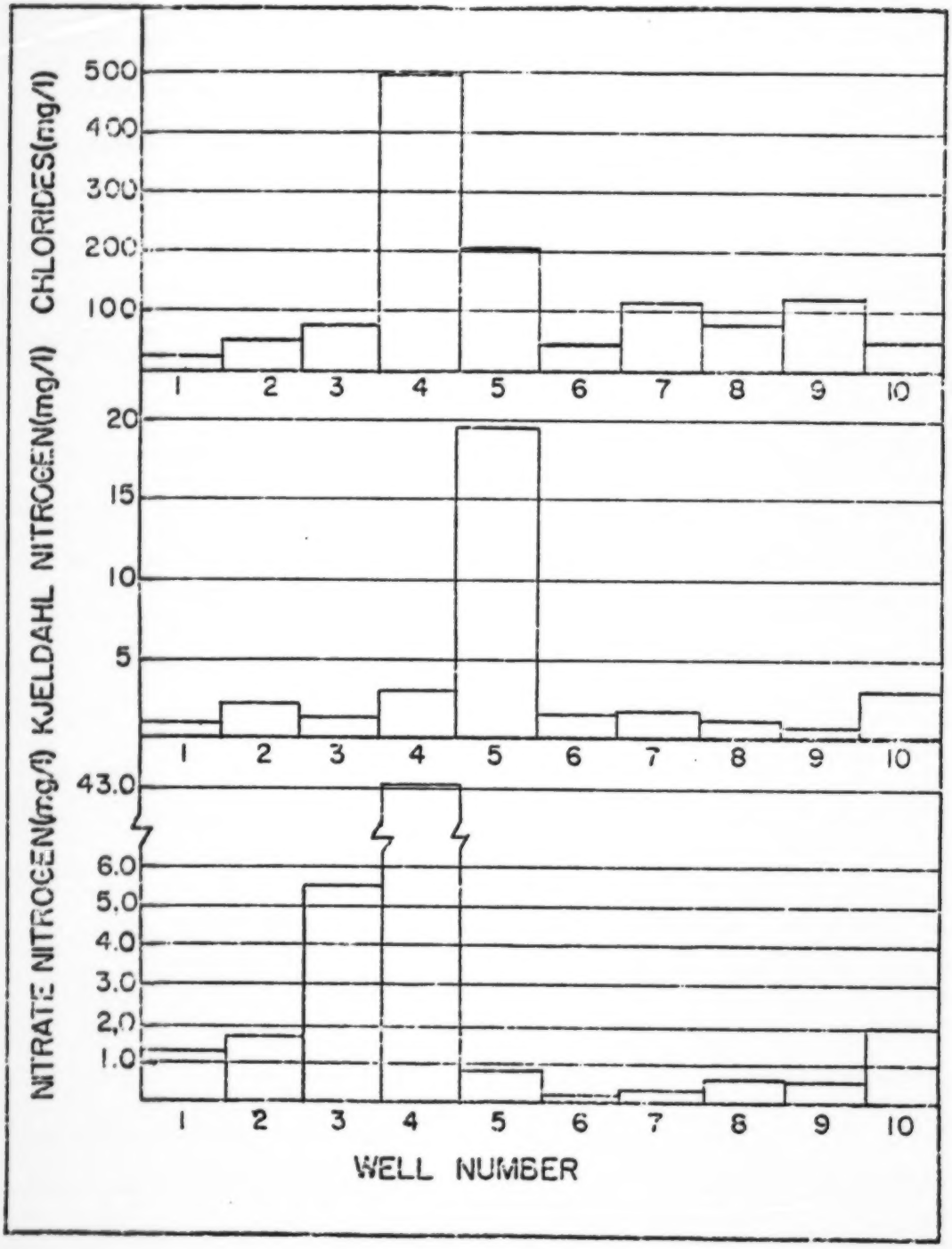


Fig. 25. Mean concentrations of chlorides, kjeldahl nitrogen, and nitrates at the individual wells.

Chlorides in concentrations above 250 mg/l give water a salty taste. Only the groundwater encountered at well 4 contained chloride concentrations in excess of 250 mg/l. However, the mean chloride concentration of the groundwater encountered at well 5 was 203 mg/l, which was substantially higher than other concentrations obtained in the immediate vicinity of the terraces. Wells 4 and 5 encountered groundwater more injurious for irrigation purposes when considering chlorides.

The presence of a high kjeldahl nitrogen concentration was also encountered at well 5; while a substantially lower kjeldahl nitrogen was obtained from the other wells in the immediate vicinity of the terraces. These kjeldahl nitrogen results would indicate that the terraces were not affecting the groundwater in the vicinity except possibly for an area near well 5. The chloride and kjeldahl nitrogen concentrations in control wells 1, 2, and 3 were relatively low and comparable to concentrations at most other wells in the immediate vicinity of the terraces.

Nitrates were low in the runoff from the BBU and, correspondingly, the groundwater sampled in the immediate vicinity of the terraces was low in nitrates. Well 4, which was out of the influence of the terraces, encountered groundwater unusually high in nitrates. As a general rule, the control wells tended to be higher in nitrate concentrations than were the sampling wells in the immediate vicinity of the terraces (see Figure 25).

Unfortunately, the chemical analyses that were performed were not sufficiently complete to illustrate the major differences among wells. For instance, wells 7 and 10 had specific conductance values indicative of a high dissolved solids concentration; however, these two wells were

not exceedingly high in any of the specific chemical constituents determincd in this study. Perhaps some benefits may have been realized if the concentrations of more chemical constituents had been determined for the groundwater encountered at these well sites. Wells 7 and 10 were, however, relatively low in contaminants common to the runoff originating at the BBU and it could be concluded that these wells encounter groundwater not greatly affected by the terraces.

Influence of Runoff on Groundwater Variations

Table 5 contains information concerning the quantity of runoff entering the terraces from the BBU as determined by personnel of the Water Resources Institute. The volumes of runoff entering the terraces from March 1, 1972, to November 28, 1972, are shown as a cumulative five-day volume in cubic feet and gallons in order to allow for better graphical representation.

Table 4 and the results of analyses of the water contained in terrace 1 indicate that the runoff from the BBU was high in kjeldahl nitrogen, BOD, COD, chlorides, and solids and had a high pH. None of the wells, with the exception of well 5, contained water that approached the chemical quality of the runoff entering the terraces. This information could indicate that the soil base of the terrace system was removing most of the contaminants found to be entering the terraces in the runoff from the BBU. Similarly, it could indicate that the water held in the terraces flowed in a northerly direction toward the coal storage and old refuse disposal area; although groundwater level information indicated the contrary.

Figures 26 and 27 were drawn to illustrate the relationship of

Table 5. Runoff Entering the Drying Terraces in 1972.

Time Period	Runoff Entering Terraces cubic feet	gallons
Mar. 1 to Mar. 10	0	0
Mar. 11 to Mar. 15	1170	8750
Mar. 16 to Mar. 20	860	6430
Mar. 21 to Mar. 25	465	3480
Mar. 26 to April 20	0	0
April 21 to April 25	780	5840
April 26 to April 30	0	0
May 1 to May 5	1180	8830
May 6 to May 10	0	0
May 11 to May 15	4790	35,800
May 16 to May 20	0	0
May 21 to May 25	2000	14,950
May 26 to May 31	9050	67,600
June 1 to June 15	0	0
June 16 to June 20	820	6130
June 21 to July 5	0	0
July 6 to July 10	1570	11,720
July 11 to July 15	1450	10,830
July 16 to July 20	3040	22,750
July 21 to July 25	636	4,760
July 26 to July 31	2800	20,950
Aug. 1 to Aug. 20	0	0
Aug. 21 to Aug. 25	5790	43,300
Aug. 26 to Sept. 10	0	0
Sept. 11 to Sept. 15	5810	43,500
Sept. 16 to Oct. 10	0	0
Oct. 11 to Oct. 15	456	3420
Oct. 16 to Oct. 31	0	0
Nov. 1 to Nov. 5	7940	59,300
Nov. 6 to Nov. 10	125	935
Nov. 28	Sampler Removed	
Total	50,732	379,275

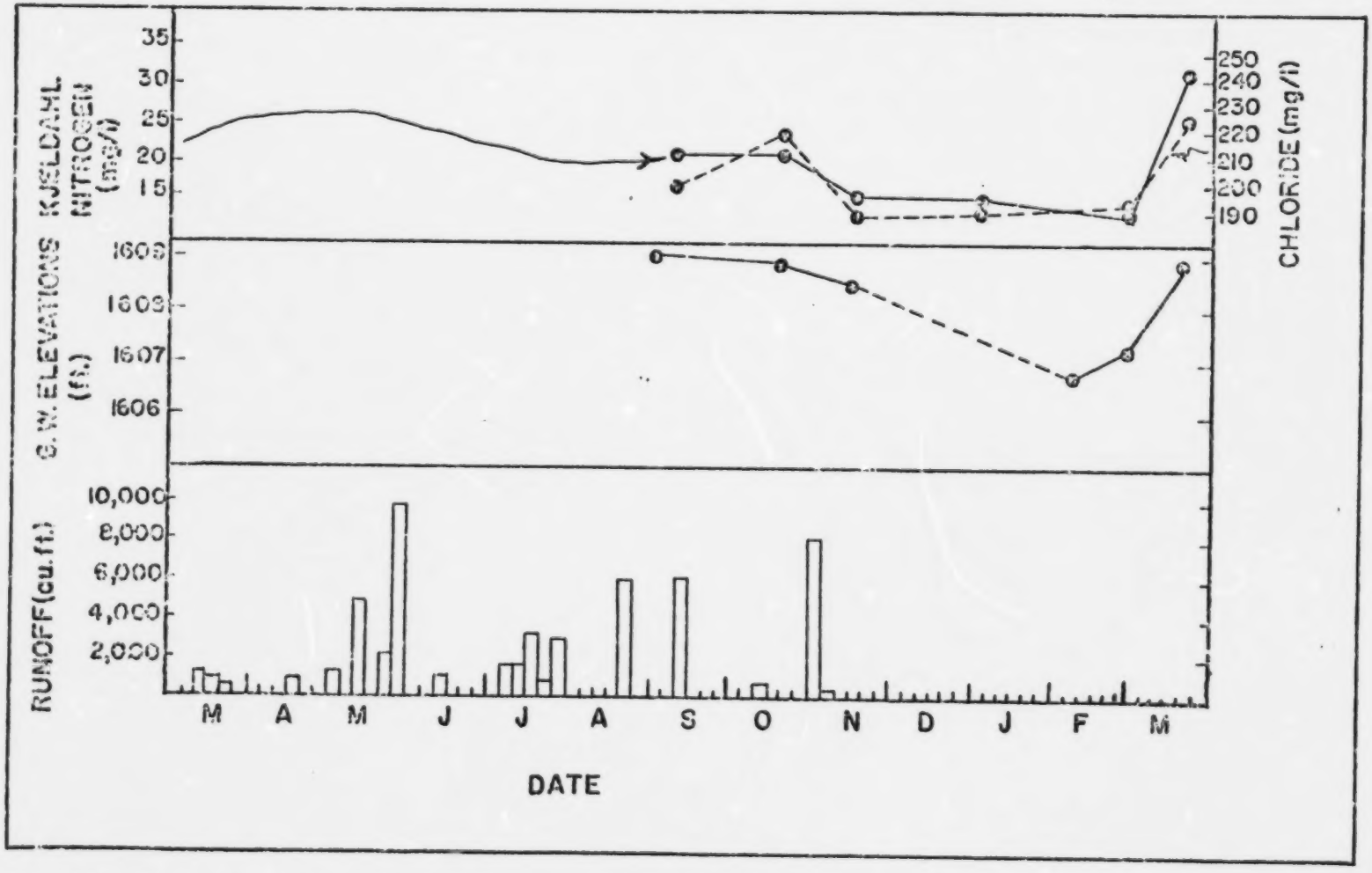


Fig. 26. Variation of groundwater elevation, chlorides, kjeldahl nitrogen, and runoff entering terraces at well 5.

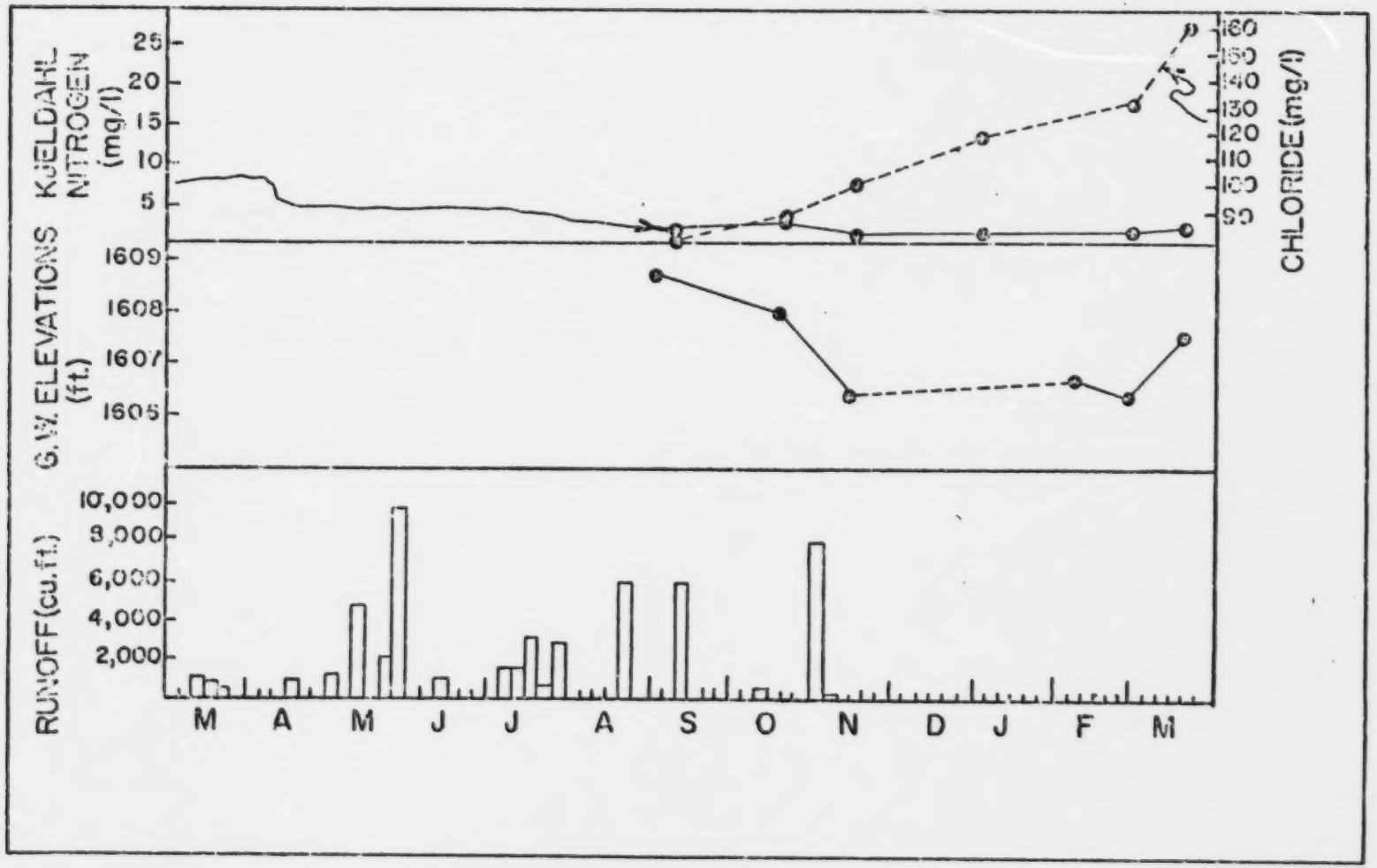


Fig. 27. Variation of groundwater elevation, chlorides, kjeldahl nitrogen, and runoff entering terraces at well 7.

the amount of runoff entering the terraces to the groundwater elevations and the chloride and kjeldahl nitrogen concentrations at two sampling sites. Runoff quantity is portrayed in the figures as a cumulative five-day runoff event measured in cubic feet (cu ft). These runoff quantities were determined using a two-inch, type H flume located at the entrance to terrace 1.

Figure 26 illustrates the effects of runoff entering the terraces on groundwater elevations and groundwater quality variations on well 5. Well 5 was chosen to be investigated because of the high chloride and kjeldahl nitrogen concentrations obtained from this well during the study. It was felt that if the terraces were affecting the groundwater in the vicinity of well 5, the variations in groundwater elevations and quality at well 5 would correspond to the quantity of runoff entering the terraces.

Groundwater elevations were not determined in January prior to sample collection and for this reason a dashed line was drawn in Figures 26 and 27 for the period between November 17, 1972, and January 8, 1973. Also, sampling of the groundwater in the vicinity of the terraces did not begin until September, 1972, although measurements on runoff quantities entering the terraces began in March, 1972.

Figure 26 shows that neither groundwater elevation changes nor chloride and kjeldahl nitrogen concentration variations at well 5 corresponded with the amount of runoff entering the terraces during the groundwater study period. There was a rise in groundwater elevations indicated after February 9, 1973, and in chloride and kjeldahl nitrogen concentrations indicated after March 3, 1973. However, these changes could not be attributed to the terraces as they were empty prior to and

during this period of time. The changes are more likely related to spring thaw conditions which existed at the time. These results indicate that the variations in groundwater elevations and quality encountered at well 5 were not directly related to the terraces. It would seem that the results obtained at well 5 were influenced by another source of contamination with characteristically high chloride and kjeldahl nitrogen concentrations. A possible source for the contaminants could be the coal storage and old refuse disposal area, where an ash disposal area is located.

Figure 27 illustrates the relationship between the runoff entering the terraces and variations in groundwater elevations and chloride and kjeldahl nitrogen concentrations that occurred at well 7. Well 7 is located near the southwest corner of the third terrace. Terrace 3 contained water from June, 1972, to late November, 1972. A large depression, located outside the south edge of terrace 3, also remained wet from June to November. Because well 7 was located in an area that was superficially influenced by the third terrace, it was deemed prudent to investigate the influence of water entering the terraces and the variations in groundwater elevations and chloride and kjeldahl nitrogen concentrations that occurred at well 7.

During the period from September and November, a period when terrace 3 contained water, and during most of the winter months the groundwater elevation in well 7 receded. This result would tend to indicate that the groundwater encountered at well 7 was not influenced by the terraces.

It can be seen from Figure 27 that the kjeldahl nitrogen concentrations obtained from well 7 remained low and relatively constant

during the investigation; while the chloride concentration steadily increased during the investigation. The changes in kjeldahl nitrogen and chloride concentrations resulting at well 7 could be related to the influence of the terraces. Soil systems have the ability to assimilate ammonia and organic nitrogen, while soil systems do not inhibit the movement of the chloride ion to any great extent. The effects of the soil could explain why kjeldahl nitrogen concentrations remained relatively constant, while the chloride concentration increased. The increasing chloride content at well 7 during the period from September through March could also indicate the water from the vicinity of well 4 located to the south of well 7 was moving into the area. At well 7, there was also a general increase in specific conductance (see Figure 7), which could indicate an increase in dissolved material in the groundwater as did the chloride results.

The effects of the terraces shown at well 7 were not conclusive. As was shown, the variations in chloride concentration at well 7 could indicate that the terraces were influencing the groundwater near the southwest corner of terrace 3. However, the groundwater elevations showed little relationship to the runoff entering the terraces. Because the variations in chloride concentration did not correspond to groundwater elevations, it cannot be conclusively stated that the terraces were influencing the groundwater encountered at well 7.

Conclusions

From the information gained in this investigation the following conclusions can be made:

1. The direction of groundwater movement was in a west-northwest

direction from the terraces toward wells 6 and 8. The terraces seemed to have little influence on this direction of flow.

2. The general quality of the groundwater in the vicinity of the terraces was poor.
3. Chloride results and groundwater elevation results were confusing. Groundwater movement, as determined in this investigation, was toward wells 6 and 8; yet these wells encountered groundwater with the lowest chloride concentration, indicating that the terraces were actually improving the groundwater quality in the vicinity.
4. Well 5 encountered groundwater with high chloride and kjeldahl nitrogen concentrations, constituents common to the runoff from the BBU. Groundwater elevations indicated that the groundwater movement from the terraces was in a direction not intercepting well 5. This movement would indicate that another source of pollution, such as the ash pit located in the coal storage and old refuse disposal area, was contaminating the groundwater in the vicinity of well 5. The above conclusion is supported by the results indicating that variations in groundwater quality and elevation at well 5 did not correspond to the quantity of runoff entering the terraces.
5. The groundwater encountered at well 7 seemed to be influenced by the terraces, as there was a noticeable increase in the chloride concentration encountered at well 7 during the period of this investigation.

In general, the results obtained in this investigation indicated that the drying terraces are not deleteriously affecting the groundwater in the vicinity. Results from well 5 seemed to indicate that sources other than the drying terraces were contaminating the groundwater in the vicinity. The probability exists that the runoff impounded in the terraces was, for the most part, evaporating into the atmosphere in which case the terraces would not contaminate the groundwater in the vicinity. Also, the soil system underlying the terraces could be removing potential contaminants from the seeping runoff. On the other hand, the possibility exists that the water seeping from the terraces moves in a northerly direction through the coal storage and old refuse disposal area. If the water seeps in a northerly direction, the wells drilled for this investigation would not clearly or adequately define the influence of the terraces on the groundwater.

The above statements serve to document the difficulties encountered during the course of this investigation. The terraces are located in an area not conducive to the type of groundwater survey performed in this study. The investigation was hampered, in particular, by snow drifts blocking routes of accessibility to the well sites, by factors limiting the placement of sampling wells to an area directly west of the drying terraces, and by soil conditions limiting the yield of wells making the process of obtaining a representative sample difficult. These difficulties were compounded by those site conditions mentioned previously.

PART C. RETURN OF WASTE TO LAND AT RATE WHICH WILL NOT INHIBIT PRODUCTION

A feedlot operator may consider livestock waste as a liability or as a resource capable of reducing fertilizer costs. Land area available for disposal and the distance which the waste must be hauled to a disposal area are important factors which influence the real value of the material. An operator with little or no available land and large quantities of waste to be removed from the feedlot generally view the land as a disposal dump with limited regard for land productivity. His prime interest is in odor, fly and rodent control, and pollution potential to the groundwater and surrounding area. An operator with sufficient land to serve as a receiver for the waste can reduce fertilizer costs and enhance soil properties by proper application rates. His interest may still be in high application rates to adjacent lands because of hauling costs. This research was directed toward the operator with the interest in maximum rates of manure application and still retain or enhance crop production.

Soon after this work was initiated it was recognized that there were factors not included in the original plan that needed to be evaluated in order to make the proper management decisions on manure disposal. It was planned essentially to apply beef cattle manure at three rates based on the nitrogen content of the manure. A series of alternate crop rotations were to be used in conjunction with the application rates. Major omitted factors which were deemed necessary in the research are the effect of the type of ration consumed by the cattle which produced the manure and the environment of the cattle while being fed. Other

critical factors which were omitted included various soil type factors, climatic conditions, and economic effect on the production of beef if potential pollutant compounds (primarily NaCl) were limited in the ration. The evaluation factors in the original plan included crop production of the land, analytical determinations of nitrogen, phosphorus, potassium, pH, electrical conductivity and total solids in the top six feet of the soil. BOD and COD in surface runoff waters were also to be measured.

Since the financial resources were not available in this project to include this expanded need, the research management decision was made to use resources available to initiate the preliminary work needed to accomplish the overall objectives. Additional financial resources were found while the initial work was underway. Therefore, the more comprehensive objectives have been fulfilled. This project served as a catalyst for additional funding from other sources. No funds were expended for this part of the project after FY 1974. This report will include the scope of the work as perceived with the additional resources and the initial preparatory work which was completed.

Scope of the Work of the Comprehensive Approach:

The purpose of the project was to develop guidelines relating climate, waste, soils, and crops to assist livestock feeders in cold regions in developing waste management techniques that are environmentally acceptable while retaining crop production capabilities. The specific objectives were:

1. Evaluate the effects of roughage content and salt content of the ration upon amount and composition of wastes from beef cattle in confined feedlots.

2. Evaluate the influence of covered versus open pens upon the chemical and physical properties of wastes to be removed from the pens.

3. Determine the maximum application rates for disposal of wastes on the land compatible with maintaining reasonable levels of crop production with pollution control.

4. Determine the concentration and movement of chemical and bacteriological waste components by surface runoff or leaching through the soil under the prevailing climatic conditions.

5. To determine if, under dryland conditions, the salts present in manure applied to the land would accumulate in the root zone to levels high enough to seriously limit crop production.

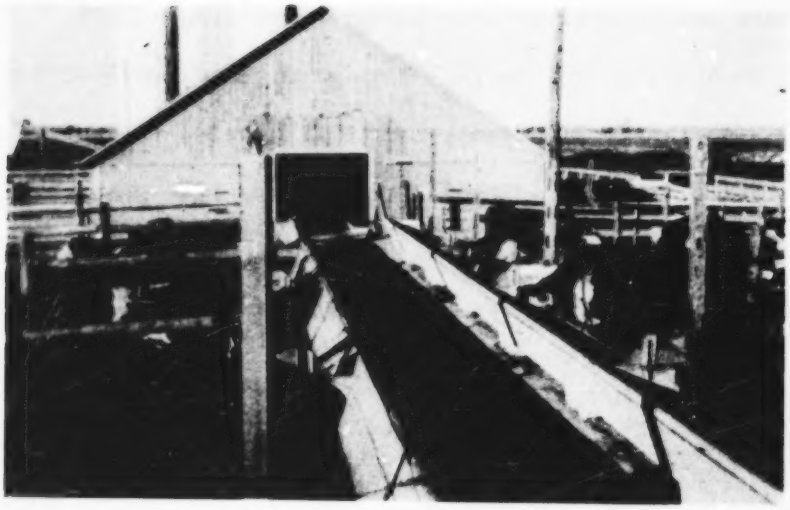
6. To determine if the ratio of monovalent to divalent cations present in manure would upset the balance of these cations in the soil and cause soil structure problems.

7. To determine if the salts and organic matter added by the manure would affect the ability of the soil to transmit water.

8. To determine the effect of applied wastes upon the quantity and quality of runoff waters.

Procedures:

The project was located at the Southeast South Dakota Experimental Farm located in the southeastern part of the state. The barn was remodeled in order to have eight covered concrete surfaced pens with separate feeding and waste collection systems and eight concrete surfaced open pens. Figure 28 illustrates the configuration of the arrangement. Treated wood partitions were placed between the pens to prevent mixing of the wastes. On July 27, 1973 eleven steers weighing about 450 lbs. were placed in each of the 16 pens, each steer having an equivalent of



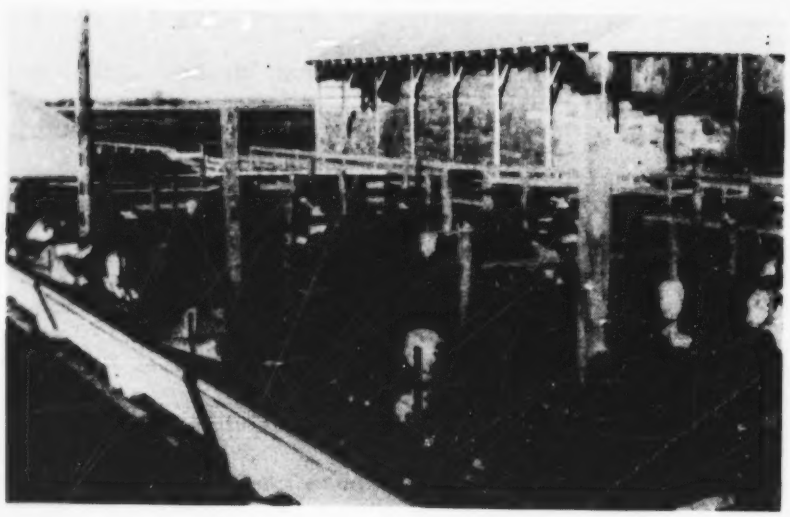


Fig. 28. Feedlot facilities.

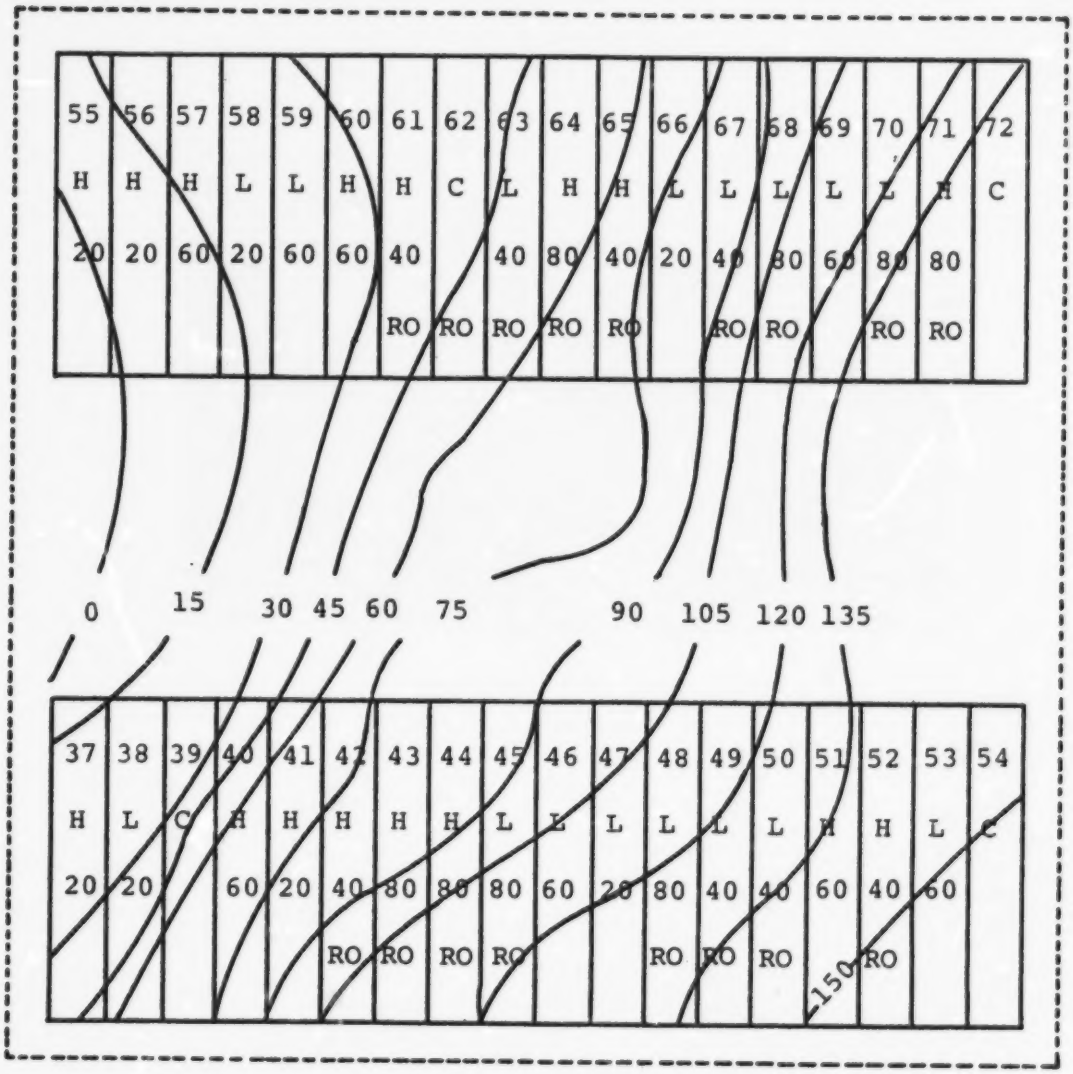
36 square feet of space. A ration consisting primarily of silage was fed during the first half of the feeding trial and one including a concentrate, primarily ground corn, was fed the second half. Four levels of NaCl were established in four different rations--0.00%, 0.25%, 0.50% and 0.75% on a dry weight basis. This arrangement offered sixteen variables with two replications, four NaCl levels, two environments and two types of rations. Standard cattle and feed management procedures were followed. A second identical feed trial was completed by the expanded project after this project closed. It started on September 11, 1974.

The wastes were removed and spread directly on the field plots whenever possible. Figure 29 illustrates the plot arrangement and the four rates at which the waste was applied. Waste incorporation and plot preparation are shown in Figure 30. Standard tillage and planting practices were used for raising the corn.

Runoff collection equipment was installed on 17 plots. The equipment is shown in Figure 31.

In October 1973, soil samples were taken from all plots using a Giddings soil sampler with a 1.3 in. diameter probe. Three sub-samples collected in each plot were pooled to form one sample. Samples were collected at depth increments of 0 to 12 in., 12 to 24 in., 24 to 36 in., and 36 to 60 in. In September, 1974, all 36 plots were again sampled in the manner described above which is illustrated in Figure 32.

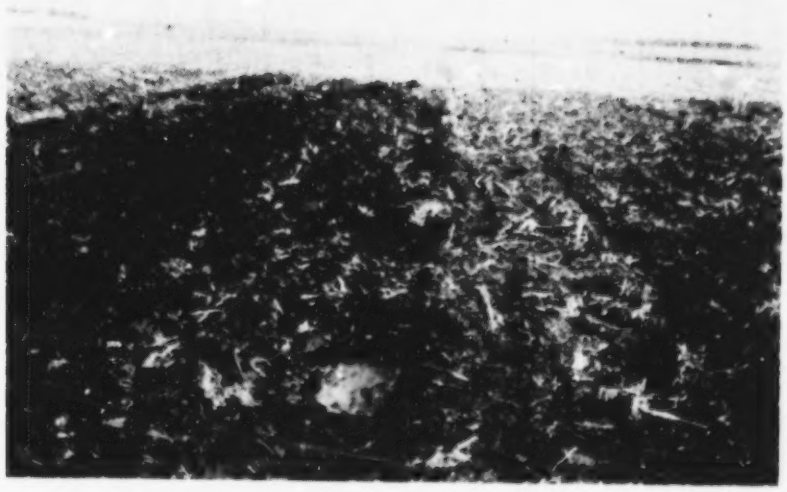
Soil samples taken in October 1973 and September 1974 were analyzed for pH and for both extractable and water soluble Ca, Mg, Na, and K. Water soluble Ca, Mg, Na, and K were obtained from analysis of the saturated extract by atomic adsorption. Extractable Ca, Mg, Na, and K



KEY TO PLOTS

37-72	Plot number	20	44.8 MT/ha.
H	High NaCl treatment	40	89.6 MT/ha.
L	Low NaCl treatment	60	134 MT/ha.
C	Check	80	179.2 MT/ha.
RO	Runoff devices		
-15-	Relative elevations in 15 cm intervals		

Fig. 29. Field plots showing relative elevations.



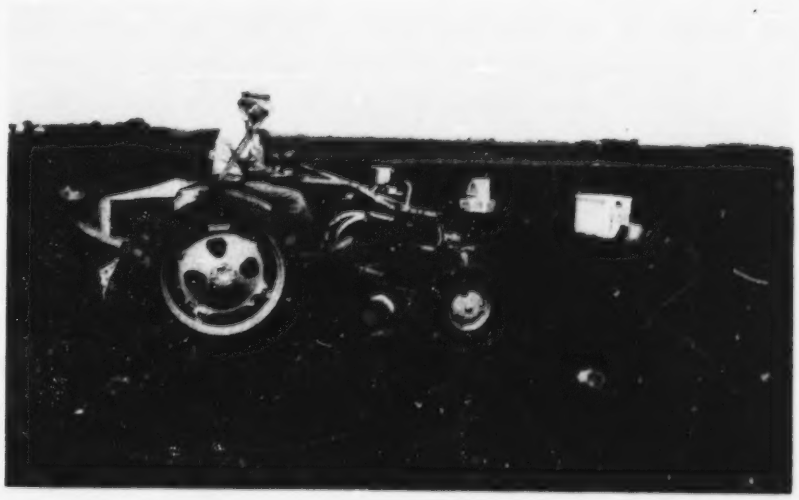


Fig. 30. Waste incorporation and plot preparation.

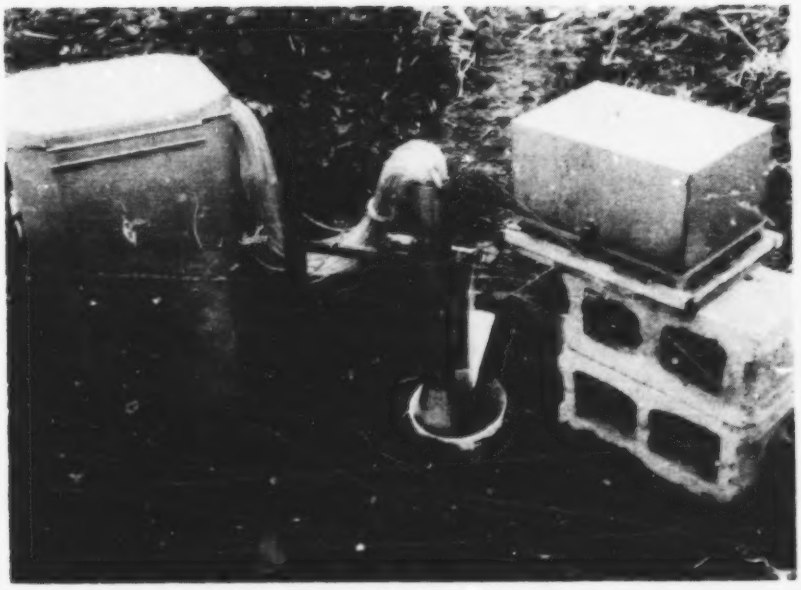
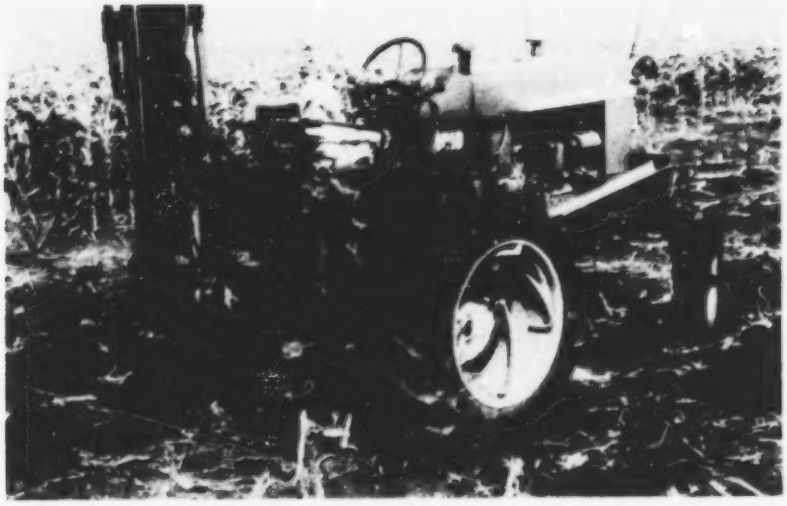


Fig. 31. Runoff field installation.



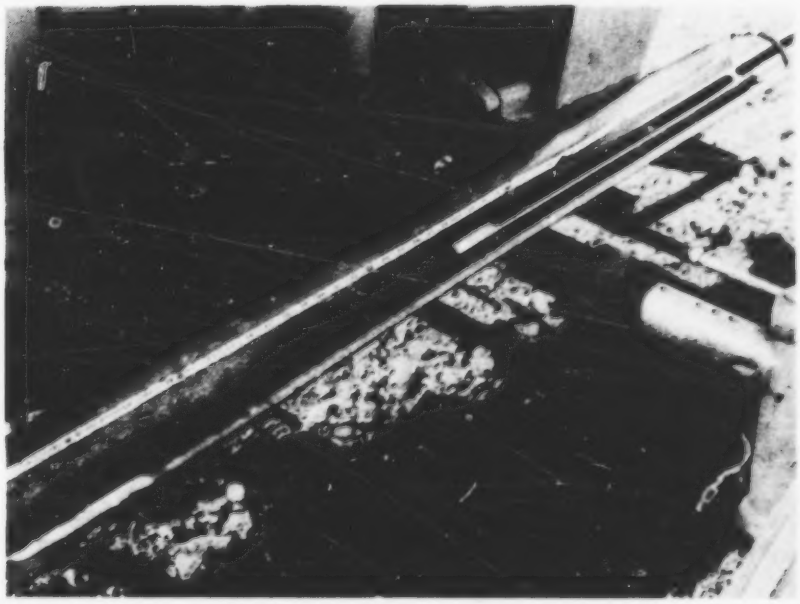


Fig. 32. Soil sampling.

were determined by an atomic adsorption analysis of an NH_4Ac extract (U.S. Salinity Laboratory Staff, 1954). Electrical conductivity was determined using the saturated extract. Soil pH determinations were made on the soil's saturated paste. Chlorides were obtained by analysis of the saturated extract. Soil analyses were also made for available P (NH_4F extractable), organic matter, and total N.

Results and Conclusions:

Only preliminary results and conclusions could be made before the research was assumed by the grant from the Environmental Protection Agency. The conclusions are available through Environmental Protection Technology Series EPA-600/2-76-188 entitled "Animal Waste Management in the Northern Great Plains". The work has been continued with an expected additional EPA publication to be forthcoming in 1980.